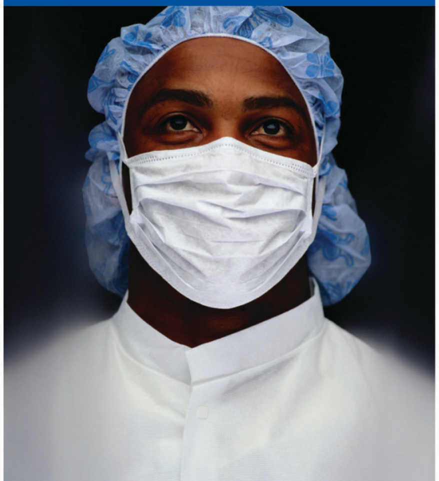

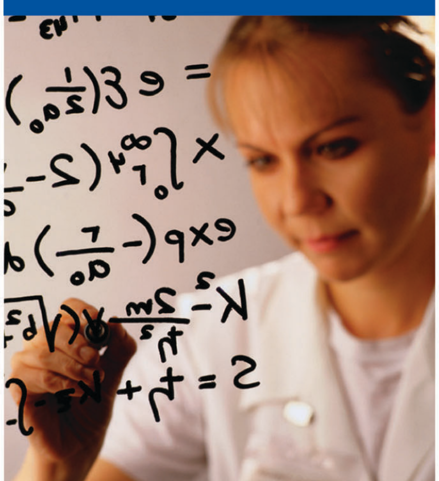

ARIZONA BIOSCIENCE
WORKFORCE STRATEGY:

PREPARING FOR THE FUTURE

PREPARED FOR:
The Maricopa Community Colleges in collaboration with the Arizona Department of Commerce, Pima Community College, Yavapai College and the Flinn Foundation

PREPARED BY:
Technology Partnership Practice
Battelle Memorial Institute
Cleveland, Ohio

October 2003

Battelle
The Business *of* Innovation

Arizona Bioscience Workforce Strategy:

Preparing for the Future

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Technology Partnership Practice

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October 2003

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Executive Summary

The biosciences are emerging as an important driver for economic growth and improved quality of life in Arizona. Fueled by major new public and private investments in the state's bioscience research base, Arizona is well on its way to establishing a critical mass of research needed for advancing new health care technologies and breakthrough therapies for the diagnosis and treatment of diseases, as well as for fostering bioscience industry development.

Given the focus on growing the bioscience cluster in Arizona and the importance of talent pools for the success of that effort, a coalition of education and government leaders recognized that the time is ripe for Arizona to take stock of its position in bioscience workforce development and put in place a strategic approach for addressing identified needs and opportunities for bioscience workforce development in the state.

The sponsors of this effort are Maricopa Community Colleges in collaboration with the Arizona Department of Commerce, Pima Community College, Yavapai College, and the Flinn Foundation. These sponsors retained the Technology Partnership Practice of the Battelle Memorial Institute to assist in preparing this workforce development strategy. Battelle's efforts were guided by a Project Advisory Group composed of representatives of education, industry, and government.

This strategic assessment of Arizona's bioscience workforce development is focused on developing a fact-based understanding of Arizona's demand for bioscience workers across the bioscience cluster and how it is aligned with the state's current capacity to generate trained bioscience workers. The study takes into account the workforce needs across the broad range of bioscience subsectors found in Arizona's bioscience cluster, rather than being limited to only one particular subsector. The study also looks comprehensively across bioscience occupations, with the exception of those directly involved in clinical care, such as physicians, nurses, and other clinical care providers. These occupations are excepted because other efforts to study and address shortages in nursing and clinical care are already under way. Mostly, an understanding of the bioscience occupations outside of clinical care has been missing.

Critical to the strategic assessment was a strong outreach to industry and educational institutions, including an extensive bioscience labor demand survey, in-depth one-on-one interviews with bioscience executives across the wide range of bioscience subsectors, interviews with higher educational institutions and state educational agencies, and three focus group meetings held across the state with industry representatives and educational providers.

> "The next generation of workforce development policies must engage the private sector and the entire public-private enterprise of training and education, starting in elementary and secondary school and continuing through college and working life. In this vision, workforce policies no longer address the "second chance" systems as they have in the past, but they are customized to the needs of individuals and employers and are linked closely to the economic priorities of states and communities."
>
> National Governor's Association, "A Governor's Guide to Creating a 21st-Century Workforce," State Leadership in the Global Economy Task Force, page 12, 2002.

Arizona Can Be Positioned for "Next Generation" Workforce Development Approaches

Arizona has an opportunity to put in place a "next generation" workforce development approach that aligns in a more fundamental and sustainable manner the demand for bioscience workers across the full spectrum of educational and training providers.

The need for such a next generation approach for bioscience workforce development in Arizona clearly emerges from the detailed study of demand and supply factors for bioscience workforce development. ***While Arizona is expected to experience robust employment growth in bioscience employment across key technical occupations spanning research, laboratory sciences, and production and management support, there is a clear mismatch in the specific areas of demand and key trends in supply***.

Substantial New Hiring in the Biosciences Expected for Arizona: The survey of bioscience employers showed that expected new hires in the next two years will reach 1,202 workers among those responding, a healthy 20 percent of current employment levels (Table ES-1).

Table ES-1: Survey Results for Job Categories

Job Categories	Number of Existing Workers	New Hires Last Year	Current Vacancies	Expected Hires, 03-05	Percent of Expected Hiring to Existing Workers
Research	727	89	38	166	23%
Laboratory Technicians	1,681	364	148	535	32%
Production-related	2,083	188	78	309	15%
Management Support	1,599	232	81	192	12%

Broad Demand for Postsecondary Education for Many Bioscience Positions: A surprising result from the survey of bioscience employers is that many are seeking workers with at least a bachelor's degree (Table ES-2). While this is not surprising for research scientists or engineers, it is surprising how frequently employers are seeking a bachelor's or higher degree for research lab technicians, engineering technicians, and management support occupations involving marketing/sales, quality assurance, and technical support.

Table ES-2: Frequency Distribution of Employer Interest in Educational Requirements by Job Function

Job Function	No Post Secondary Required	2 year degree required	BA required	Require Advanced Degree	Hire Direct from Education
Product R&D Engineer		7%	67%	53%	53%
Research Scientist		0.03%	48%	79%	62%
Medical Lab Technician	76%	74%	64%	29%	98%
Research Technician	29%	41%	82%	29%	88%
Forensics	77%	77%	15%	8%	23%
Manufacturing & Production	94%	39%	28%	6%	100%
Engineering Technician	77%	80%	53%	7%	90%
Process Development Engineer		10%	80%	10%	70%
Marketing Sales	33%	45%	64%	7%	50%
Technical Support/ Documentation/Logistics	66%	56%	91%	7%	90%
Quality Assurance/Validation	20%	43%	78%	35%	53%
Regulatory Affairs		34%	75%	53%	44%
Health/Bio-Informatics	57%	67%	71%	19%	95%

Mismatch in Demand and Supply for Bioscience Workers: Despite the promising signs of job gains in the biosciences, Arizona has some key challenges in aligning supply with demand.

Examples of specific areas of mismatch include the following:

Laboratory sciences. A significant and growing bioscience occupational area for Arizona is found in laboratory sciences, spanning both health care and research environments. Yet, few educational programs today address this need, and existing programs (especially in the health care laboratory) suffer from low enrollments.

*Large generation of biology students lacking employable laboratory skills***.** Arizona stands out in the growth of its biology degrees, particularly at the undergraduate level, growing by 15 percent compared to just 1% nationally. The number of biology-related majors now stands at nearly 900 annually in Arizona. However, these biology students are generally poorly prepared to undertake the hands-on laboratory work required in healthcare and research settings. And the trend is to fewer laboratory instructional experiences for students in Arizona.

Lack of educational and training curricula in regulatory affairs and quality assurance for medical devices. Beyond the fact that medical devices are Arizona's largest nonclinical bioscience industry and production workers the largest occupational grouping employed by bioscience employers, there is no active effort to provide training for workers entering that highly regulated environment with specific quality standards.

Graduate degree programs in the biosciences are falling just as the demand for postdoctoral scientists in Arizona is soaring. Arizona has recorded a sharp decline in Ph.D. and master's graduates in the biosciences in recent years. Yet, a strong demand for research scientists is expected in Arizona in the next several years, with most of the positions to be filled by recent advanced degree graduates.

Underpinning these demand and supply mismatches in Arizona are deeper issues that must be addressed, including the following:

- The disconnect between bioscience employers and educational institutions in sharing information, setting priorities, developing needed programs, and addressing the curriculum
- Lack of capacity in the biosciences across the educational system, especially for specialized programs and advanced degrees
- Limited awareness by Arizona residents—particularly school-age youth and those seeking new careers—of the opportunities to pursue bioscience careers, and a need for proactive steps to increase access to these career opportunities, especially among minority populations.

At the same time, as the economic priorities of Arizona are placing a clear emphasis on the bioscience cluster, opportunities exist for Arizona to make workforce development a key driver and contributor to an overall bioscience economic development strategy for the state. Workforce development can provide both a resource for emerging and start-up bioscience ventures in Arizona and an advantage to attract investments and operations from existing bioscience companies, particularly from the West Coast.

Key Findings from Best Practices

The benchmarking analysis of leading and peer states in bioscience workforce development raised a number of important findings shaping how Arizona can effectively address its strategic needs:

- **Significant industry involvement.** This is perhaps the most universally held success factor found across programs in the benchmark states. As one program director explained: "Because they work so closely with industry, the students are trained exactly as industry needs them."
- **Broad range of students to be served.** Building an effective educational pipeline for the biosciences requires both traditional community college to 4 year degree program linkages as well as non-traditional post-baccalaureate and continuing education courses for those who have already having earned a four-year degree in the biosciences and those in the workforce.
- **New focused efforts needed to build an educational pipeline for the biosciences.** Successful program articulation in bioscience career education to bachelor-degree level calls for new types of degree programs at the four-year level. These programs are needed to recognize the value of hands-on skills curriculum offered at the community college level.
- **Challenge of developing curricula for bioscience workforce and career development.** Unlike IT certification, biotech lab technicians, biomanufacturing, ag biotech, and biomedical engineering lack national certifications. Given the lack of standardization in defining skills and techniques, it is important to have resources available to support continual development of curricula.

- **Difficulties in experiential learning and internships.** For bioscience positions, it is often difficult to place students in traditional internship programs because of regulatory requirements and the size of companies. Other approaches to experiential learning and exposure to industry need to be developed, such as having industry instructors, creating pilot facilities, and focusing on capstone projects.
- **Lack of statewide coordination.** A patchwork of programmatic efforts with little scale or strategic focus is emerging across the benchmark states, making it difficult to gain resources to support the growth of needed programs. A few states, notably California and Washington, are coming close to addressing this need for coordination.

Vision and Mission

The vision for Arizona's bioscience workforce development can be summarized as follows:

> *Arizona will succeed in its bioscience workforce development efforts by establishing a demand-driven bioscience workforce approach that broadly emphasizes access to bioscience careers for Arizona residents.*

The state's mission is that, a decade from now, the outside world will acknowledge the following:

> Arizona educational and training institutions are recognized as having a highly collaborative partnership with bioscience employers that spans broadly across educational institutions at all levels, serving to
>
> - Enable Arizona to identify specific occupational and skill needs based on timely information gathering and specific mechanisms that translate employer needs into on-the-ground programs and curricula
> - Reach out to students, parents, and those workers seeking to change careers or advance in the biosciences.
>
> The responsiveness and agility of Arizona's advanced bioscience workforce system serve as a competitive advantage for the state not only in helping to grow home-grown Arizona bioscience companies, but in attracting investments from companies outside of Arizona.

Strategies and Actions

Addressing the demand and supply gaps in a systematic and sustainable manner that pinpoints the underlying challenges as well as seizes the economic development opportunities calls for a specific set of strategies and actions for Arizona.

Five specific strategies are proposed to accomplish this vision and achieve this mission:

- Strategy One: Advance bioscience career pathways to integrate industry needs for bioscience workforce in a seamless fashion across broad spectrum of educational institutions.
- Strategy Two: Promote access to bioscience careers and ensure that the bioscience career initiatives serve Arizona's diverse population.
- Strategy Three: Build capacity across educational institutions for bioscience workforce development that can be broadly shared and leveraged.
- Strategy Four: Conduct ongoing strategic assessment in a manner that institutionalizes the continued evaluation of bioscience workforce demand and alignment with supply to guide program and curriculum development and advance outreach efforts.
- Strategy Five: Establish an economic development focus that positions bioscience workforce development as a proactive tool for economic growth for the state.

Altogether 26 specific action steps have been identified across the five strategic priority areas. Table ES-3 presents these strategies and actions.

Table ES-3: Summary of Proposed Strategies and Actions with Priorities and Time Frames

Strategy	Actions	Priority	Time Frame
Strategy One: Advance bioscience career pathways	Establish a statewide bioscience industry-education council to foster strong partnerships, involving ongoing industry guidance on program offerings and career pathways.	Critical	Immediate
	Prioritize the development of bioscience programs based on a systematic process that aligns the demand and core skill sets in existing and emerging career pathways with ongoing educational program offerings and curricula.	Critical	Near term
	Design 2+2+2 career preparation programs rather than stand-alone degree efforts.	Critical	Near term
	Ramp up laboratory sciences across the state in a defined career pathway approach.	Significant	Long term
	Address education and training development needs for careers in biomedical production and related management support occupations.	Significant	Long term

Table ES-3: Summary of Proposed Strategies and Actions with Priorities and Time Frames (continued)

Strategy	Actions	Priority	Time Frame
Strategy Two: Promote access to bioscience careers and ensure that bioscience career initiatives serve Arizona's diverse population	Undertake a broad public marketing effort on bioscience careers that raises the public's understanding of bioscience career opportunities and specifically targets students, parents, and guidance counselors.	Significant	Near term
	Offer specific bioscience career awareness activities in K-12 involving enriched educational experiences with experiential learning opportunities.	Critical	Immediate
	Develop specialized approaches, such as broad-based mentorship and extracurricular efforts, to reach out to at-risk minority and economically disadvantaged students from the early grades.	Significant	Near term
	Ensure that personalized services for minority, economically disadvantaged, and at-risk students found in K-12 and community colleges are continued as students progress at the four-year and graduate levels.	Significant	Immediate
	Work with industry to create customized retraining programs for current nonbioscience workers who demonstrate an aptitude to enter bioscience careers.	Critical	Near term
	Focus on bioscience skill upgrading for those trained in the biosciences or in existing bioscience positions, including postbaccalaureate programs.	Significant	Near-term

Table ES-3: Summary of Proposed Strategies and Actions with Priorities and Time Frames (continued)

Strategy	Actions	Priority	Time Frame
Strategy Three: Build capacity across educational institutions for bioscience workforce development that can be broadly shared and leveraged	Develop a shared, common vocabulary on bioscience workforce terminology.	Critical	Start immediately or as soon as possible, but will be long term
	For identified fields of biosciences, focus on developing industry-driven skill standards translated into core curricula to ensure comprehensive, high-quality, and responsive program efforts.	Critical	Immediate
	Pursue shared-use approaches for deploying program resources statewide.	Critical	Near-term
	Dedicate funding for recruitment of topflight bioscience graduate students to Arizona.	Important	Long term
	Develop a clearinghouse capability to broaden communications across students, employers, educational institutions, and parents on bioscience careers, educational opportunities and requirements.	Important	Long term
	Strengthen K-12 math and science programs (Project Lead The Way, enrichment activities, etc.).	Critical	Long term
Strategy Four: Conduct ongoing strategic assess-ment in a manner that institutionalizes the continued evaluation of bioscience workforce demand and alignment with supply to guide program and curriculum development and advance outreach efforts	Develop ongoing occupational and skill needs assessment of employers, using regular vacancy surveys, occupational profiling, and other techniques.	Significant	Immediate
	On a periodic basis, complete surveys of bioscience workers to learn their educational and training needs.	Important	Long term
	Develop a specialized labor market research capability under the guidance of the bioscience industry-education council.	Significant	Near term
	Using the forum of the bioscience industry-education council, convene regular industry-education dialogues to discuss trends and issues arising across bioscience fields.	Critical	Immediate

Table ES-3: Summary of Proposed Strategies and Actions with Priorities and Time Frames (continued)

Strategy	Actions	Priority	Time Frame
Strategy Five: Establish an economic development focus that positions bioscience workforce development as a proactive tool for economic growth for the state.	Develop and market bioscience workforce capacities targeted to specific bioscience industry segments within niche areas of bioscience activity where Arizona has broad-based competitive advantages.	Critical	Immediate
	Provide matching funds for the development of specific company-based curriculum and program needs to be served through postsecondary institutions based on guarantees of job hires.	Significant	Near term
	Establish programs targeted to postdocs serving at Arizona academic institutions as prospective industry scientists and entrepreneurs.	Important	Long term
	Develop a pilot biomanufacturing program in Arizona as a lead investment for targeting recruitment of biomanufacturing facilities to the state.	Important	Long term
	Provide relocation assistance and other services to help in the recruitment of senior business executives and scientists by emerging and start-up bioscience firms.	Important	Near term

Critical Actions

This strategic assessment notes 11 critical actions out of the 26 action steps identified. These critical actions are essential if Arizona is to accomplish its vision of a demand-driven bioscience workforce system that emphasizes access to bioscience careers for Arizona citizens. They include the following:

- Establish a statewide bioscience industry-education council to foster strong partnerships, involving ongoing industry guidance on program offerings and career pathways.
- Prioritize the development of bioscience programs based on a systematic process that aligns the demand and core skill sets in existing and emerging career pathways and with ongoing educational program offerings and curricula.
- Design 2+2+2 career preparation programs rather than stand-alone degree efforts.
- Offer specific bioscience career awareness activities in K-12 involving enriched educational experiences with experiential learning opportunities.
- Work with industry to create customized retraining programs for current nonbioscience workers who demonstrate an aptitude to enter bioscience careers.
- Develop a shared, common vocabulary on bioscience workforce terminology.

- For identified fields of biosciences, focus on developing industry-driven skill standards translated into core curricula to ensure comprehensive, high-quality, and responsive program efforts.
- Pursue shared-use approaches for deploying program resources statewide.
- Strengthen K-12 math and science programs (Project Lead The Way, enrichment activities, etc.)
- Using the forum of the bioscience industry-education council, convene regular industry-education dialogues to discuss trends and issues arising across bioscience fields.
- Develop and market bioscience workforce capacities targeted to specific bioscience industry segments within niche areas of bioscience activity where Arizona has broad-based competitive advantages.

Immediate Actions

But, as the old adage goes, "actions speak louder than words." It also is important that Arizona seize the opportunity to accomplish "immediate" actions that can be implemented within a 6- to 12-month period to demonstrate progress and build momentum.

These six immediate actions are identified as part of this strategic assessment:

- Establish a statewide bioscience industry-education council to foster strong partnerships, involving ongoing industry guidance on program offerings and career pathways.
- Offer specific bioscience career awareness activities in K-12 involving enriched educational experiences with experiential learning opportunities.
- Ensure that personalized services for minority, economically disadvantaged, and at-risk students found in K-12 and community colleges are continued as students progress at the four-year and graduate levels.
- For identified fields of biosciences, focus on developing industry-driven skills standards translated into core curricula to ensure comprehensive, high-quality, and responsive program efforts.
- Develop ongoing occupational and skill needs assessment of employers, using regular vacancy surveys, occupational profiling, and other techniques.
- Using the forum of the bioscience industry-education council, convene regular industry-education dialogues to discuss trends and issues arising across bioscience fields.
- Develop and market bioscience workforce capacities targeted to specific bioscience industry segments within niche areas of bioscience activity where Arizona has broad-based competitive advantages.

SUMMARY

This strategic assessment is not an end in itself, but a beginning to help Arizona move forward. It sets out a baseline and blueprint for engaging more fully the broad stakeholders in Arizona.

If Arizona can move forward on these initiatives, and use the demand and supply side intelligence gathered by this study to guide new program developments, then it will have a strong bioscience workforce component to its overall bioscience roadmap effort. This analysis sees Arizona's bioscience workforce development strategy being driven by an understanding of its demand needs and ensuring that the supply generated by educational and training institutions is aligned with these demand requirements. Given the important role that talent pools are playing in advancing the knowledge economy and particularly the biosciences, it is expected that this investment in bioscience workforce development can pay significant dividends in the years ahead, while being realistically balanced by the needs of bioscience employers.

Introduction

Arizona is on the road to building a strong bioscience cluster. A recently completed Arizona Bioscience Roadmap suggests that, with strong public and private leadership and long-term commitment, Arizona can achieve the following vision in the next 10 years:

> ***Arizona is a leading Southwestern State in selective bioscience subsectors, built around world-class research, clinical excellence, and a growing base of cutting-edge enterprises, and supporting firms and organizations.***

At the heart of this bioscience roadmap is the realization that the biosciences are emerging as an important driver for economic growth and improved quality of life in Arizona. Fueled by major new public and private investments in the state's bioscience research base, Arizona is well on its way to establishing a critical mass of research needed for advancing new health care technologies and breakthrough therapies for the diagnosis and treatment of diseases, as well as for fostering bioscience industry development.

Without a doubt, having a growing research base provides the "innovation driver" needed for developing and sustaining a thriving bioscience cluster. Given the especially close connections between research discoveries and new product developments in the biosciences, as well as the key role of academic health centers in bridging the gap between basic and applied research through clinical research, it is not surprising that having a growing robust research base is critical to sustaining ongoing bioscience cluster development.

An economic impact assessment of the proposed Arizona Bioscience Roadmap actions, amounting to total investments of nearly $1.3 billion, suggests that Arizona can increase its private sector industrial bioscience employment base three-fold over the next 10 years, from growth of existing bioscience employers to new companies formed. This significant growth suggests that workforce development must be an important consideration as Arizona goes forward.

So, hand in hand with innovation goes the need for a talent pool of skilled bioscience workers to generate, translate, and put into practice this innovation. At its core, the bioscience sector is a knowledge-based cluster dependent upon the skills of its workers. Bioscience workers are needed to conduct research, translate innovation into product development and improved health care techniques, and ultimately to manufacture biomedical and other bioscience-related products and apply technologies for improved health care.

Thus, ensuring the availability of an educated, skilled workforce is key to developing and sustaining a highly competitive, robust bioscience cluster over the long term. Those states that effectively address these workforce needs will be in a stronger position to grow and develop their bioscience clusters.

> "The contemporary economic process is driven by innovation and the rapid economic adoption of innovations, both of which are facilitated by well-educated and highly trained workers. This is why innovation and human capital are seen as the limiting factors in the new economy, and it is why the production and expansion of these resources is so important."
>
> John Ahlen and Mark Diggs, "The Keys To Economic Growth:Investing in Discovery," Engineering and Entrepreneurship, Capital Resource Corporation, February 2003.

Given the focus on growing the bioscience cluster in Arizona and the importance of a talent pool for the success of that effort, a coalition of education and government leaders recognized that the time is ripe for Arizona to take stock of its position in bioscience workforce development and put in place a strategic approach for addressing identified needs and opportunities for bioscience workforce development in the state. The sponsors of this effort include the Maricopa Community Colleges in collaboration with the Arizona Department of Commerce, Pima Community College, Yavapai College, and the Flinn Foundation.

These sponsors retained the Technology Partnership Practice of the Battelle Memorial Institute to assist in preparing this workforce development strategy. Battelle's efforts were guided by a Project Advisory composed of educational, industry, and government representatives. Battelle's Technology Partnership Practice brings a strong understanding of the dynamics and requirements for growing a bioscience cluster, along with proven expertise in technology workforce development, including work in such states as Connecticut, Michigan, Georgia, Indiana, Missouri, and Colorado, and was responsible for developing Arizona's Biosciences Roadmap, prepared for the Flinn Foundation and released in December 2002. Battelle brings a well-grounded understanding of the bioscience industry and research base in Arizona and is currently working with the Flinn Foundation and other stakeholders to support ongoing implementation of key initiatives contained in the Biosciences Roadmap, including this effort in workforce development.

STATE-SPECIFIC NEEDS FOR BIOSCIENCE WORKFORCE DEVELOPMENT

Each state pursuing bioscience development must contend with the following challenges to workforce development:

The fast pace of innovation drives new skill development in the biosciences. Following the successful completion of the Human Genome Project, another era of innovation is being unlocked, creating new areas of research and application from bioinformatics to proteomics to tissue engineering. At the same time, progress in microelectronics, robotics, biomaterials, and nanotechnology is establishing new avenues for advancements in medical devices, drug delivery, and surgical practices. In the future, this confluence of events will put serious demands on current educational and training providers to meet this changing skill set to generate qualified workers who meet the specific skill needs of that state's research and industry base.

Critical skill shortages can emerge quickly in the biosciences and pose major impediments to industry growth in particular niche areas. For example, developing new "biologic" drugs requires new biopharmaceutical production technologies and skills. Bioscience industry analysts at McKinsey and Company point out the impact of workforce gaps for this growing area of biotechnology: "What is less well understood is the biologics-manufacturing talent shortfall: the industry faces a looming shortage of the highly trained people needed to design, build and operate facilities. Experienced process-development scientists and engineers, validation engineers, quality assurance personnel and plant managers are already in short supply."[1] These same dynamics can be true in other niches from medical devices to health care delivery.

At the same time, the bioscience sector is very broad and diversified, encompassing research, manufacturing, and service activities; and its demand for workers is correspondingly very diverse, calling for specific technical skills across a spectrum of skill levels.

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[1] Mallik, A., Pinkus, G., and Sheffer, S. "Biopharma's Capacity Crunch," *The McKinsey Quarterly 2002 Special Edition: Risk and Resilience.* McKinsey & Company, 2002, pp. 9-11.

Despite popular public perceptions, the bioscience workforce is not solely the domain of those few individuals with Ph.D.'s and M.D.'s. It is interesting to note that, nationally, the highest share of employment opportunities in the biosciences is found in production and technician positions, typically requiring associate's and bachelor's degrees. Nationally, production occupations comprise more than 50 percent of occupations found in medical devices, more than 40 percent in the pharmaceutical industry, and more than 30 percent in agricultural chemicals. Even in hospitals, the largest percentage of occupations is found in nursing and health care support occupations.

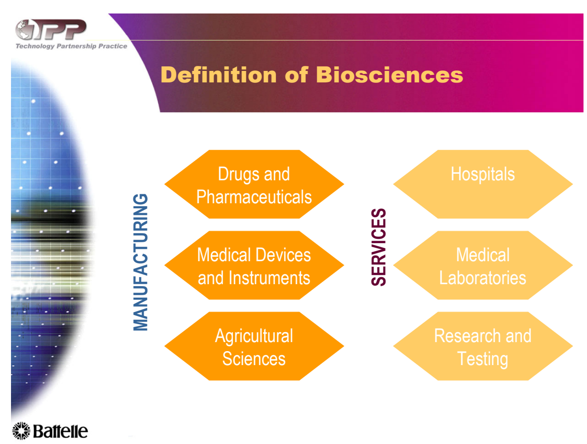
These challenges are not unique to any one state. However, the activities and opportunities for states in the biosciences are not uniform and, in turn, that reflects on the skills being demanded. Some states are best suited to be leaders in medical devices, while others are specializing in agricultural biotechnology or research and testing or drug development. Even within these areas of specialization, there are major differences in niches (e.g., between orthopedic development and surgical instruments in medical devices) that influence the specific skills in demand.

These challenges to bioscience workforce development call for responding to the specific needs found within a state, rather than pursuing a one-size-fits-all solution. The specific technologies in the biosciences being advanced will vary, as will the specific niche opportunities being pursued and the mix of bioscience activities found in the state. There is no one-size-fits-all solution for any state's bioscience workforce development, but rather a need to think globally about key trends and best practices, but applied with strong guidance by the local situation.

PROJECT FOCUS AND METHODOLOGY

This strategic assessment of Arizona's bioscience workforce development is focused on developing a fact-based understanding of Arizona's demand for bioscience workers and how it is aligned with the state's current capacity to generate trained bioscience workers.

Figure 1: Definition of Biosciences



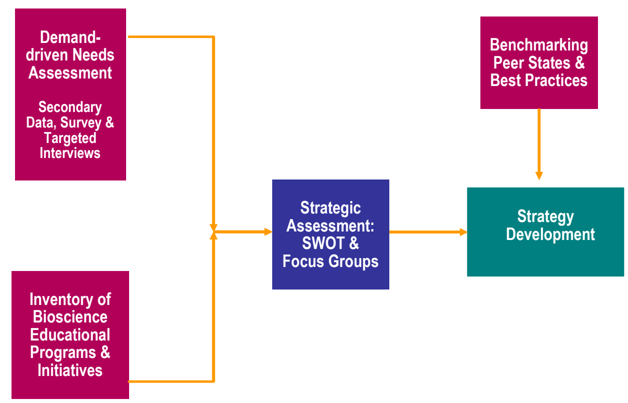
The study takes into account the workforce needs across the broad range of bioscience subsectors found in Arizona's bioscience cluster, rather than being limited to only one particular subsector. These bioscience subsectors include hospitals and medical laboratories, medical devices and instruments, drugs and pharmaceuticals, agricultural sciences, and research and testing (Figure 1).

The study also looks comprehensively across bioscience occupations, with the exception of those directly involved in clinical care, such as physicians, nurses, and other clinical care providers. These occupations are excepted because other efforts to study and address shortages in nursing and clinical care are already underway. Mostly, an understanding of the bioscience occupations outside of clinical care has been missing.

Consequently, the specific occupations examined in this study include the following:

- Laboratory science workers including those involved in medical care, research, and forensics lab activities
- Research occupations including scientists and product development engineers
- Manufacturing occupations including production workers, engineering-related technicians, and process development engineers
- Management support occupations including marketing/sales, technical support, quality assurance, regulatory affairs, and health/bio-informatics.

Figure 2: Methodology for Strategy Development



Under the guidance of the Project Advisory Group, Battelle undertook a comprehensive methodology involving several steps for developing a bioscience workforce development strategy (Figure 2):

- ***Assessing the Demand for Bioscience Workers in Arizona***, reporting on the results from Battelle's in-depth demand analysis including survey, data analysis, interviews, and focus groups
- ***Inventorying Educational Activities,*** reporting on the trends in bioscience workforce graduates and emerging trends in educational offerings for bioscience careers
- ***Preparing a Situational Analysis,*** providing a strategic assessment of the strengths, weak-nesses, opportunities, and threats facing Arizona in bioscience workforce development
- ***Conducting a Best Practices and Benchmarking Analysis,*** examining how other leading and neighboring states are approaching bioscience workforce development and presenting best practice lessons for Arizona to consider
- ***Developing a Strategic Framework and Initiatives,*** presenting how Arizona can develop a demand-driven bioscience workforce system that emphasizes access to bioscience careers for Arizona citizens.

Critical to the strategic assessment was a strong outreach to industry and educational institutions, including an extensive bioscience labor demand survey, in-depth one-on-one interviews with bioscience executives across the wide range of bioscience subsectors, interviews with higher educational institutions and state educational agencies, and three focus group meetings held across the state with industry representatives and educational providers.

Broad Range of Survey, Interviews, and Focus Group Discussions Conducted

- Survey of bioscience organization's labor market demand, with responses from 73 organizations representing 65% of the state's bioscience employment base
- Detailed one-on-one interviews with executives from broad range of bioscience organizations
- Extensive interviews with representatives of higher educational institutions and statewide educational organizations to inventory bioscience base
- Three focus group discussions with industry representatives and educational providers

Demand for Bioscience Workers in Arizona

The heart of this workforce development strategy is to develop an understanding of the demand factors for bioscience occupations across the broad range of bioscience employers in Arizona. The specific demand issues to be examined include the following:

- Current position of bioscience occupations in Arizona
- Future demand for new hires across bioscience occupations
- Educational requirements for bioscience workers
- Skill requirements
- Labor market dynamics.

Gaining these insights into bioscience workforce demand required undertaking several types of analysis:

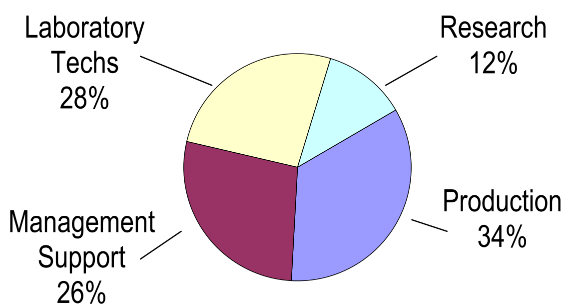
- **Review of occupational data, compiled nationally through the efforts of each state's labor market information office.** Unfortunately, lack of data availability from the state government prevented focusing on the level of various occupations employed by bioscience industry subsectors in Arizona. Instead, only occupational employment across all employers was considered, so the review was limited to bioscience research and medical laboratory occupations that are expected to be highly concentrated in the bioscience industry sector.[2]
- **Survey of workforce needs of bioscience employers in Arizona**. Battelle collected original data using a survey instrument developed in concert with the Project Advisory Group (see Appendices A and B for details of survey methodology and survey instrument) and used a comprehensive database of bioscience organizations derived from Dun & Bradstreet. Substantial efforts were made to ensure a high degree of response, including both a broad mailing to the state's bioscience employers and extensive follow-up phone calls to all bioscience employers with more than 10 employees. Altogether, 73 survey responses were obtained, representing 65 percent of total employment in the biosciences in Arizona.
- **One-on-one interviews with CEOs and senior officials from selective bioscience companies** to learn more about the hiring experiences of bioscience employers, specific skill needs in demand, and industry's knowledge and opinion of existing bioscience workforce training initiatives and activities. The focus was on gaining more insights into specific bioscience industry subsectors and their hiring needs.

[2] Battelle was seeking information developed as part of the Occupational Employment Survey which cross-walks occupations by industry classifications, often referred to as the "occupational matrix." However, after repeated discussions with the state's Labor Market Information Office to obtain these data by broad bioscience subsectors, these data were not made available to Battelle.

KEY FINDINGS

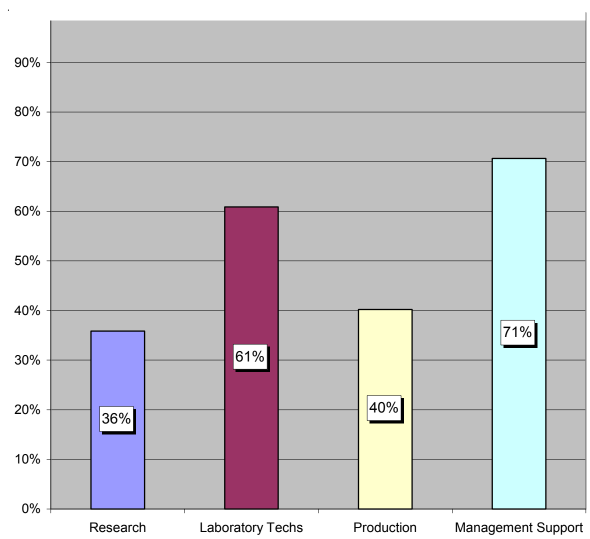
Mix Across Occupational Categories: Based on the survey of bioscience employers, the leading bioscience occupational categories in Arizona today are found in production occupations, followed by laboratory technicians and management support positions (Figure 3).

Figure 3: Category Share of Bioscience Workforce



Prevalence of Occupations Across Bioscience Employers: Not all occupations are found as frequently across bioscience employers. For instance, research scientists and engineers are found among only 36% of the bioscience employers responding to the survey, while management support occupations are found among 71 percent of the respondents (Figure 4). The prevalence of bioscience occupations across establishments should be examined in concert with the level at which people are employed in those occupations. This reveals that laboratory tech occupations are not only prevalent across establishments, but also are one of the largest occupations in terms of employment.

Figure 4: Frequency of Occupational Categories Employed by Bioscience Employers Responding to Survey



Occupational Specialization: Two occupations— biomedical engineers and medical and clinical laboratory technicians—stand out as key occupational specializations for Arizona compared with the nation, based on occupational data compiled by state Labor Market Information Office.

- The concentration of biomedical engineers in Arizona stands 85 percent higher than in the nation, reflecting the importance of medical device development in the state. It is a small occupation in Arizona with 215 workers.
- The concentration of medical and clinical laboratory technicians in Arizona stands 41 percent higher than in the nation, with more than 4,900 workers. This strong presence of medical lab technicians demonstrates the importance of hospitals and medical labs in the state.

Vacancy Rates: Overall, survey participants indicated that job vacancies account for 6 percent of total bioscience-related employment. Two key job categories—laboratory technicians and management support—account for a large number of unfilled positions. Respondents reported that 9 percent or 148 laboratory tech positions and 5 percent or 81 management support positions are unfilled (Table 1). These levels of vacancies suggest gaps between supply and demand for labor. As the bioscience industry continues to grow, it is paramount that industry be able to find an adequate supply of labor. If vacancies persist, a mismatch between the skills people possess and the skills industry demands will arise.

Table 1: Survey Results for Job Categories

Job Categories	Number of Existing Workers	New Hires Last Year	Current Vacancies	Expected Hires, 03-05	Percent of Expected Hiring to Existing Workers
Research	727	89	38	166	23%
Laboratory Technicians	1,681	364	148	535	32%
Production-related	2,083	188	78	309	15%
Management Support	1,599	232	81	192	12%

Expected New Hires: The survey of bioscience employers showed that new hires are expected to reach 1,202 workers in the next two years, 20 percent of current employment levels.

- The healthcare laboratory technician occupation is not only highly specialized in Arizona, it has the largest number of expected new hires with 341 positions or 27 percent of the current employment level.
- Bioscience production occupations, including assembly line workers, engineering technicians, and process engineers, have a high number of expected new hires at 309 positions; but, these new hires represent a moderate 15 percent above current production employment levels across those responding to the survey (Table 1).
- Growing research activity is clearly a major new driver of employment in Arizona. Compared with current employment levels, new hires are expected to reach 47 percent for research lab technicians and 39 percent for research scientists. The actual levels of expected new hires are also impressive, although they not unexpectedly fall below the larger production and healthcare technician occupations, with 160 new hires for research technicians and 132 new hires for research scientists.

Extrapolated Longer Term Estimates: An earlier economic impact analysis of the state's bioscience investments and trend analysis of existing bioscience employers, prepared by Battelle, suggests that Arizona can expect an increase of 27,285 new jobs in the biosciences from 2002 to 2012. It is expected that 9,327 of these new jobs will be found in nonclinical bioscience occupations, which were the focus of this study based on the percentage of bioscience employment that they comprise.[3] The projected increases are 3,430 jobs for bioscience production occupations, 2,610 for management support occupations, 1,766 for laboratory technicians and technologists, and 1,521 for research occupations.[4]

Educational Levels: The survey of bioscience employers surprisingly revealed that many are seeking workers with at least a bachelor's degree (Table 2). While this is not surprising for research scientists or engineers, it is surprising how frequently employers are seeking a bachelor's or higher degree for research lab technicians; engineering technicians; and management support occupations involving marketing/sales, quality assurance, and technical support.

Table 2: Frequency Distribution of Employer Interest in Educational Requirements by Job Function

Job Function	No Post Secondary Required	2 year degree required	BA required	Require Advanced Degree	Hire Direct from Education
Product R&D Engineer		7%	67%	53%	53%
Research Scientist		0.03%	48%	79%	62%
Medical Lab Technician	76%	74%	64%	29%	98%
Research Technician	29%	41%	82%	29%	88%
Forensics	77%	77%	15%	8%	23%
Manufacturing & Production	94%	39%	28%	6%	100%
Engineering Technician	77%	80%	53%	7%	90%
Process Development Engineer		10%	80%	10%	70%
Marketing Sales	33%	45%	64%	7%	50%
Technical Support/ Documentation/Logistics	66%	56%	91%	7%	90%
Quality Assurance/Validation	20%	43%	78%	35%	53%
Regulatory Affairs		34%	75%	53%	44%
Health/Bio-Informatics	57%	67%	71%	19%	95%

R&D = research and development

[3] Other key occupations among bioscience employers that were not tallied include nonbioscience administrative staff (secretaries, accountants, human resource, etc.) and clinical care staff (nurses, medical doctors, medical assistants, etc.).
[4] See the Arizona Bioscience Roadmap for full details of the economic impact analysis for private sector industrial bioscience jobs. Hospital and medical lab employment growth was estimated by looking at the historical relationship between hospital and medical lab employment growth and population growth in Arizona from 1995 to 2001. The extrapolation is based on comparing the current employment base by occupation reported in the survey for each industry subsector with the remainder put into an "other" category. The employment growth estimate is based on applying these occupational ratios to the projected increase for each sector.

Skill Requirements: Interviews with bioscience employers revealed that, while specific technical skills may vary, specific cross-cutting occupational skills need to be addressed through enhanced and expanded educational offerings. Specific employer needs dictate the technical skills required for bioscience occupations. For instance, medical device manufacturers in Arizona tend to fall into either electrical engineering disciplines or mechanical engineering and materials disciplines, which in turn affects the sets of specific technical skills required. Skill variation is probably greatest across bioscience employers involved in research activities. In the research setting, this variation reaches down to the research lab technician who may be asked to perform very different lab techniques depending upon the type of research activity undertaken.

Still, despite these variations in technical skills, what emerges across employers is a need for specific occupational skills. For laboratory technicians, skills in good laboratory practices (GLP) stand out, involving material handling, documentation, safety procedures, and maintenance of equipment and facilities. For production workers and management support, skills in biomedical quality standards and regulatory requirements stand out.

Labor Market Dynamics: There are many conflicting and complex patterns to the labor market dynamics involving bioscience employers:

- Healthcare lab technicians, for instance, generally have low turnover; but, employers are facing the challenge of an aging workforce with few new graduates in healthcare lab programs.
- The research lab technician occupation, on the other hand, is growing rapidly but tends to have a high turnover in Arizona because many workers are recent college graduates who often will go back to school or seek better career tracks in different occupations.
- For research scientists, the majority of new hires in Arizona will be postdoctoral workers, not tenured faculty. These postdocs usually will have a limited employment contract and then will seek other employment opportunities in academia or industry. It is typical for many postdocs to be recent Ph.D. students from overseas—so the ability to secure a foreign visa is critical.
- In production occupations, the labor market dynamics revolve mostly around a minority population, especially in line production positions, for whom English is a second language. Training in new skills is therefore a challenge.

A Closer Look at Survey and Interview Results by Occupational Category

This section presents a more detailed discussion of the survey results, labor market dynamics, and skill requirements by occupational category (See Appendix C for more survey results by job function.).

Research Job Category

Survey Results

The research job category is a very specialized class of occupations comprising only two job functions—product research and development engineers and research scientists. Accounting for only a 12 percent share of bioscience labor, it would seem that this is a small category with employment of 727. However, this smallest grouping of bioscience occupations contains two of the larger bioscience job functions—research scientists and product R&D engineers (Table 3).

Table 3: Job Functions in Research Job Category

Research Job Functions	Number of Existing Workers	New Hires Last Year	Current Vacancies	Expected Hires, 03-05	Expected Growth Rate, 03-05
Product R&D Engineer	385	30	15	34	9%
Research Scientist	342	59	23	132	39%

Looking to the future, the expected new hires for research scientists stand out. Over the next two years, new hires of research scientists are expected to reach 132 or a hefty 39 percent of current research scientist employment. On the other hand, lower gains in new hires—reaching only 9 percent of current employment or 34 new hires—are expected for product R&D engineers.

Examining the number of establishments that will share in this growth reveals that job functions categorized as research are the most specialized among the establishments that participated in the survey. The survey indicated that only 36 percent of responding establishments possess research-oriented occupations. This is the most concentrated employment category.

Labor Market Dynamics

The vast majority of research scientists to be hired in the next two years will be among university and nonprofit research organizations. This is to be expected, given the major investment by public and private sectors in expanding the state's bioscience research base. Interviews revealed that most of these research scientist positions will be filled by postdoctoral workers who will be filling out research teams. By and large, these postdocs will be recruited from outside of Arizona, with many coming from overseas. One of the major employment issues arising for research organizations is the difficulty of securing visas for these postdoc workers because of the recent tightening of reviews leading to long delays in issuing visas for foreign workers.

For private sector bioscience companies engaged in research, industry leaders indicate that, at present, the availability of research job functions is sufficient to meet current industry demand. This is largely because the companies engaged in R&D activities are in the early stages of technology development. Though the research job function plays a very pivotal role in the industry's development, bioscience leaders believe that the level of industry activity is not at a point where the demand for researchers exceeds the existing supply.

There is concern that, as the bioscience industry develops in Arizona, the supply of labor will not be able to keep pace with the growth in demand. Some industry executives expressed trepidation that, once the industry reaches a level of specialization and emerges as a major sector of the state economy, the labor market for technically skilled workers may be very tight in Arizona, especially in light of the low level of graduates with postbaccalaureate degrees. However, one potential source of research scientists for Arizona's industry may be the postdocs attracted to the state by research organizations based in Arizona.

Industry Requirements

Degree Level: Industry leaders usually require advanced degrees for research job functions in bioscience-related fields. To a lesser extent, companies will accept applicants with a bachelor's degree. However, across the educational spectrum, a significant amount of work experience is expected. The following are some of the educational disciplines that employers in Arizona seek:

- Analytical Chemistry
- Computational Chemistry
- Biochemistry
- Molecular Biology
- Microbiology
- Organic Chemistry
- Synthetic Chemistry
- Bioengineering
- Pharmacology
- Cellular Biology.

Technical Skills: Across the spectrum of bioscience companies, a multitude of technical skills are required to fill research job functions. Industry leaders seek applicants that encompass well-rounded capabilities across a broad range of technologies. Effective workers will possess the ability to apply this mix of skills in practical, real-life laboratory environments:

- Combinatorial chemistry
- High-throughput drug screening
- Gene expression: DNA microarray technology
- Nucleic acid transcription
- High-performance liquid chromatography
- Immunohistochemistry, histology
- Biomechanics
- Near-infrared spectroscopy
- Chemometrics
- Scanning probe microscopy
- Chemical reagent formulation
- Antibody production
- Polymerase chain reaction.

Laboratory Technician Category

Survey Results

Laboratory occupations are the second largest category of bioscience job functions. Responding establishments reported that job functions categorized as laboratory technician account for 1,681 people, or 28 percent of all bioscience positions (Table 4). The survey also indicated that laboratory technical work was among the more prevalent categories of labor found within Arizona. The survey demonstrated that 61 percent of respondent establishments possessed job functions classified as laboratory technician.

Table 4: Job Functions in Laboratory Technician Category

Laboratory Technician Job Functions	Number of Existing Workers	New Hires Last Year	Current Vacancies	Expected Hires, 03-05	Expected Growth Rate, 03-05
Medical Lab Technician	1,272	267	119	341	27%
Research Technician	344	81	25	160	47%
Forensics	65	16	4	34	52%

In addition to being the second largest category of bioscience jobs, laboratory technicians are the leading occupation category in new hires. Over the past year, 364 new laboratory technician jobs were added among survey respondents. The increase in new hires represents 22 percent of the current employment base. Projected to increase even more over the next two years, the rate of new hires among job functions within the laboratory technician category is expected to increase 32 percent from existing employment. The absolute level of new hires stands at 535 jobs, the greatest increase among all job categories.

According to respondents, 148 job vacancies presently exist in the laboratory technician category. Even though the projected level of new hires more than exceeds the number of job vacancies, this high level of unmet labor demand indicates an important labor market dynamic.

Labor Market Dynamics

The demand for laboratory technicians and technologists in hospitals and medical labs is being driven by growth in hospitals responding to population growth and the aging of the workforce in clinical labs—nationally approaching an average age in the late 40s. The key issue is that the healthcare lab technician occupation is not attracting young people to the profession—reflecting high educational requirements, long hours with shift duty and high stress, low pay, and limited career advancement opportunities. Interestingly, though, healthcare lab technicians generally are a stable workforce with minimal turnover.

A greater degree of automation has helped to offset some of the vacancy issues, but the aging of the healthcare lab technician workforce means that time is running out. Hospitals and labs have begun to address these issues by diversifying the career opportunities for lab techs across degree levels. One respondent in particular has broadened the career path of laboratory techs to better reflect critical skill needs for specific positions. This approach creates several different entry points for prospective candidates.

In contrast, research organizations—which dominate the hiring of research lab technicians in Arizona—tend to have a high turnover in these positions owing to the typical source of workers—recent college graduates. There seems to be a strong bias toward hiring bioscience graduates in research lab technician positions—instead of lab technicians with bench-tool training at the associate degree level—based largely on the perceived need for a broader depth of knowledge of the biosciences and possibly more education in general. *Interestingly, these positions require less theoretical and more bench-procedure knowledge, and most lab techs are educated and trained in this area. However, as studies for the medical technician profession are increasingly included in B.S. degree programs, community colleges and four-year schools will need to find ways to address this issue through integrated programs and life-long career development.* Often, the best recent graduates are sought as research technicians—and these recent graduates often apply to graduate school or medical school within a short time on the job.

Also, research organizations may not be willing to pay higher wages to keep workers longer. Large core labs that repeat focused laboratory procedures seem to go against this trend toward requiring bachelor's degrees. The largest core labs in Arizona are found at the Arizona Research Laboratory at the University of Arizona. Unfortunately, few large core bioscience facilities are found in Arizona, nor are planned in the near term.

Interestingly, healthcare lab technicians and research lab technicians in Arizona and across the nation are typically treated very separately in both training and hiring. Healthcare lab technicians and technologists complete a defined program of study to become licensed professionals. Research lab technicians, on the other hand, typically have recently received their bachelor's degrees and have no specific required training in licensing or laboratory procedures beyond their general biology subjects. So, hospitals and medical labs do not hire those engaged by research labs, and healthcare technicians/technologists generally do not get hired by research labs due to a lack of understanding of their skills and higher pay requirements. There is, however, isolated evidence in major bioscience concentrations of successful use of healthcare technologists in the research setting. The basic problem is that researchers who head research labs have minimal knowledge and understanding of the clinical setting and fail to appreciate or even know of the healthcare technician/technologist occupation. As Arizona and other states try to increase the focus on translational research, perhaps this cross fertilization of the medical and research settings will be rectified and an opportunity for A.S. to B.S. degree programs can mature.

Industry Requirements

Degree Level: The bachelor's degree is predominant for both healthcare lab technologists and research lab technicians. Again, for research lab technicians, this is largely a matter of preference and bias of research organizations and industry. In healthcare lab fields, there is a more structured approach to licensing. A few fields within the healthcare lab technician/technologist occupation, such as histology, have no degree requirements; but, the sophistication of equipment and techniques are pushing up the standards to at least an associate's degree. Other healthcare lab positions also can be serviced by lower degree levels, typically at the associate level, for specific types of labs such as clinical chemistry labs involved in testing for glucose, cholesterol, and enzymes. However, many of the most sophisticated clinical labs, such as those involved in virology, immunology, microbiology, blood banking and molecular testing, require technicians with a bachelor's degree or higher. Moreover, smaller regional hospital centers in more rural areas typically require a high degree of flexibility in their healthcare technicians. This required flexibility calls for a person with a bachelor's degree to assure interlab coverage.

Technical Skills: The lab tech category has a wide array of skill requirements ranging from routine repetitive laboratory tasks to higher specialized tasks requiring compiling data. Cutting across specific fields is the need for laboratory management involving documentation; following protocols; biosafety; maintaining, operating, and repairing equipment; quality assurance; and meeting regulatory requirements.

Some of the more specific skills entail the following:

- Histology
- Flow cytometry
- Cell/tissue cultures
- Microbial cultures
- Microbiology

- Media and solution preparation
- Hematology
- Virology
- Laboratory equipment operation
- Immunochemistry.

Laboratory Tech Job Profile

Title: Laboratory Tech

Responsibilities: Performs various routine technical laboratory duties and preliminary analyses. Tasks may involve assisting principal researchers in performing an array of standard or repetitive laboratory experiments or tests. Duties also will include running basic diagnostic tests and laboratory examinations. Incumbents draw largely upon their practical knowledge and experience derived from trial-and-error work.

Position Illustration: Executes standard laboratory procedures such as maintaining cell cultures requiring the use of sterile techniques, processing tissue samples and preparing slides using staining techniques. Maintains plant collections, which includes planting, fertilizing, propagating, and harvesting; performs routine experiments and analyses, as requested. Maintains animal or insect colonies, which includes feeding, watering, sexing, and breeding the subjects. Compiles data and assists in routine preliminary analyses, maintains research data in laboratory notebook, writes summary reports, and reports findings to investigator. Collects samples or data and performs lab analysis and/or quantifies and tabulates results. Operates laboratory and experimental equipment such as microtomes, microscopes, electron microscopes, spectrophotometers, centrifuges, analytical balances, photometers, and spectrometers. Packages waste material and arranges for disposal according to established procedures. Assists with basic mathematical and statistical analyses. Follows established procedures to prepare solutions, media, and reagents using arithmetical calculations for measuring; performs library research to find appropriate procedures, as required. Performs clerical tasks such as filing, typing, labeling, and billing; inventories and requisitions supplies and materials. Performs a variety of determinations on different body fluids such as pregnancy tests, urinalysis, and complete blood counts; confirms and verifies test results, and reports findings to clinicians. Collects body fluids and material such as urine, blood, and throat cultures. Performs and reviews quality controls in testing, decides whether results are within acceptable ranges, researches problems and corrects. Develops and/or modifies existing procedures and policies for the operation of the laboratory. Develops and implements quality control systems for testing, ensures continued compliance with licensing requirements.

Production Job Category

Survey Results

Production-oriented jobs represent the largest portion of bioscience employment among respondents. According to the bioscience workforce survey, respondents employ 2,083 production-oriented workers (Table 5). However, this category of employment is not the most pervasive type of bioscience work in Arizona. Production jobs are concentrated among select respondents that are primarily manufacturers as opposed to major research facilities. The survey demonstrated that 40 percent of respondents reported some level of production-oriented worker.

Job functions categorized as production are increasing. Establishments that answered the survey indicate that the number of new hires since 2002 represents 9 percent of the current employment level. This growing trend of new hires among the survey participants is projected to continue over the next two years. Between 2003 and 2005, new hires are expected to represent 15 percent of the current employment base. The result will be an addition of 309 new production-oriented jobs. This employment increase represents the second largest increase of bioscience workers.

Table 5: Job Functions in Production Job Category

Production Job Functions	Number of Existing Workers	New Hires Last Year	Current Vacancies	Expected Hires, 03-05	Expected Growth Rate, 03-05
Manufacturing & Production	1,502	147	62	251	17%
Engineering Technician	337	27	6	30	9%
Process Development Engineer	244	14	10	28	11%

Although not among the faster growth job categories, the production jobs category has the lowest vacancy rate. Respondents reported in the survey that 78 vacant positions exist across the various production job functions. This level of job vacancy represents only 3.7 percent of the current employment base. The data suggest that the supply of labor demanded for production jobs is readily available within the state of Arizona. The implication is that employers are able to avoid lengthy searches for qualified employees.

Labor Market Dynamics

Presently, employers find the current labor supply of production workers sufficient to meet demand. However, interviews with industry executives pointed to complex issues facing bioscience employers engaged in production activities, issues such as diversity of the workforce and meeting the challenges of regulatory compliance and quality standards.

The production workforce is very diverse, with many workers who do not possess strong English skills. Companies have found that training is critical in dealing with the diverse backgrounds of employees. At the same time, the importance of training is even more significant because of the need to meet strict U.S. Food and Drug Administration (FDA) regulations.

Industry leaders also expressed that, with the convergence of industries, new production workers will be required to possess multiple skills. Existing in-house and outsourced training programs have provided workers with the skills they need. However, bioscience production functions may change with the introduction of new information technology and biologic materials. Industry leaders are unsure how this change will affect the labor market and how training programs should be altered to adapt.

Industry Requirements

Degree Level: The job functions within the production category have very clear degree requirements, but do not necessarily translate into a structured career pathway.

Individuals with extensive manufacturing experience and/or a high school diploma usually join the labor market for production jobs at the entry level. However, quality control and production process management and design positions typically call for a bachelor's degree. The role of associate degree workers is not clear within production work—in some organizations, associate degree workers can serve in more analytical positions on the shop floor. So, different career positions based on education cover a wide chasm between shop floor work and more high-level quality control and process engineering. Individuals who possess an advanced degree typically are involved with R&D activities, not production work.

The following educational disciplines are essential for production:

- Machining
- Electronics assembling
- Electrical engineering
- Mechanical engineering
- Industrial engineering
- Bioengineering
- Microbiology
- Biomechanics
- Analytical chemistry
- Synthetic chemistry.

Technical Skills: Combined with the expansive nature of the production category in terms of career paths and the very nature of bioscience production, workers are required to possess a wide range of technical skills. Bioscience-related production requires that individuals not only be familiar with commonplace manufacturing skills and techniques, but also have a certain level of scientific understanding. Bioscience products also are held to a higher standard to assure product safety and quality. Individuals are therefore expected to have some of the following skills according to their position and industry segment:

- Good Manufacturing Practices (GMP)/GLP
- Instrumentation validation
- FDA regulatory compliance
- Materials coding/bonding
- Chemical reagent formulation
- ISO 9001
- Programming
- Production assembly.

Production Job Profile

Title: Production Specialist

Responsibilities: Performs a combination of various routine and/or technologically sophisticated production functions. Tasks may include engineering, manufacturing, and formulation. Proficient in automated manufacturing equipment/systems. Contributes to product quality assurance and control through conceptualization and implementation of enhanced manufacturing processes.

Position Illustration: Supports and participates in day-to-day manufacturing. Takes part in transitioning new products and implementing new scale-up manufacturing processes. Follows established procedures to measure and formulate solutions and reagents. Evaluates production runs based on analysis of regulatory requirements and product quality. Runs testing scripts and other validation procedures to assure products fall within acceptable manufacturing parameters. Draws upon a wide range of engineering and production knowledge and skills focused on fabricating components using high-tech raw materials. Operates and maintains production equipment. Meets project timelines and commitments. Assists in the design and fabrication of engineered components, electrical circuits, equipment, and integrated systems. Assists in troubleshooting systems and equipment and performs repairs under close supervision. Requisitions components and supplies for production runs, interacting with vendors to obtain price and product information. Highly specialized in mechanics, electronics, and software controls that configure, control, and drive manufacturing equipment.

Management Support Category

Survey Results

Jobs that function as support for other key bioscience occupational tasks are the most diverse category of jobs. The bioscience workforce survey indicated that 1,599 workers are employed in some support capacity (Table 6). Workers categorized as management support perform a wide range of assistance activities including marking and sales, documentation and logistics, quality assurance, regulatory affairs, and health/bio-informatics.

Table 6: Job Functions in Management Support Category

Management Support Job Functions	Number of Existing Workers	New Hires Last Year	Current Vacancies	Expected Hires, 03-05	Expected Growth Rate, 03-05
Marketing Sales	634	93	38	60	9%
Technical Support/ Documentation/Logistics	550	89	15	77	14%
Quality Assurance/Validation	317	43	21	31	10%
Regulatory Affairs	53	3	6	13	25%
Health/Bio-Informatics	45	4	1	11	24%

The diverse nature of this job category explains why management support occupations are so pervasive among respondents. The survey indicated that 71 percent of establishments possessed some aspect of work categorized as management support. This is the most common job category among establishments.

This category of bioscience employment has experienced healthy gains; in the past year, 232 new jobs were added, representing 15 percent of the current employment base. However, respondents do not expect this rate of increase to continue because the demand for management support workers is expected to decline.

Between 2003 and 2005, the survey projected that jobs within the management support category will experience the smallest level of new hires compared with current employment levels, reaching only 12 percent. The nature of management support suggests that the future role of jobs in this category is highly dependent upon the level of overall bioscience industrial activity.

Labor Market Dynamics

Industrial leaders have suggested that management support job functions are not very specialized positions. Typically, establishments with a small labor force require workers to perform these tasks in addition to other more technologically sophisticated duties. Small companies expect workers to wear several hats and have the ability to multitask. Presently, workers across the spectrum of job functions are expected to have the knowledge sufficient to support overall business activities.

As the Arizona bioscience industry matures and scales up, management support jobs become more distinct, requiring a greater degree of specialization for each job function. Data management and documentation, along with product quality and assurance, are critical in the bioscience industry. The FDA requires bioscience companies to follow strict regulations. Some industry leaders have found a need to hire individuals who perform certain management support functions exclusively, although this has not become a common occurrence yet. Employers foresee that, once the bioscience industry emerges as a major source of economic growth, the importance of management support job functions will increase as a result of strict federal guidelines.

Industry Requirements

Degree Level: The majority of new hires possess a bachelor's degree, but companies occasionally have hired people with advanced degrees and associate degrees as well. The current status of the bioscience industry makes it difficult to encapsulate the management support job category. Each employer tends to utilize the management support job functions in different capacities, making it extremely difficult to characterize the career path for these types of occupations. Because management support occupations are so pervasive, a host of disciplines are applicable. Typically, the management support category incorporates a broad range of basic liberal arts degrees. Some of these areas include the following:

- Biology
- Chemistry
- Process engineering
- Business administration—sales and marketing
- Computer science.

Technical Skills: The wide-ranging nature of the management support category requires new hires to possess a breadth of technical skills. Some of these skills overlap with other job categories. However, within the field of management support, individuals tend to possess the following skills in positions that are typified as managerial or analytical:

- Quality assurance/control
- Regulatory affairs
- Statistical analysis
- Sales and marketing
- Database management
- Procedural documentation.

Inventory of Bioscience Educational Activities in Arizona

The following analysis depicts the key factors shaping the pipeline of bioscience workers in Arizona from the supply side of educational and training providers. This discussion is approached by examining

- Recent trends in bioscience graduates relative to the nation
- Programmatic developments throughout the educational pipeline, including leading programs
- Key challenges that must be either strengthened or addressed to develop the pipeline of bioscience workers that industry will demand in the future.

The focus of this analysis was on those certificate and degree programs focused on bioscience-career-specific and workforce-related skills development. In reviewing the state's efforts, the focus was not on efforts to promote more traditional educational activities in the biosciences, such as postsecondary degrees in biological sciences, except when identifying where they relate to programs and initiatives designed to provide students with relevant workplace skills for bioscience workers.

Recent Trends in Bioscience Graduates

Many fields of study outside of direct patient care draw upon the biosciences. The key bioscience fields nationally are the more basic-science-related biology degree programs, but the more applied bioscience degree programs also relate to specific industry sectors such as

- Biotechnology and medical products
- Medical sciences applying biosciences to understanding human diseases and health
- Medical laboratory sciences involved in testing and analysis to detect human illness
- Agricultural and plant sciences
- Agricultural animal sciences
- Food and nutrition sciences
- Environmental sciences
- Chemistry and material sciences.[5]

A national database maintained by the National Center for Educational Statistics (NCES) was used to review bioscience degree trends for Arizona. The NCES database allows for comparisons of Arizona to national trends, as well as key competitive states. The data that NCES compiles is obtained directly from the states, and the Arizona Board of Regents has reviewed the data for Arizona and validated its accuracy.

[5] See Appendix D for detailed degrees found under bioscience degree categories.

Overall, Arizona awarded 1,717 bioscience-related degrees in the 2000–2001 school year. As Table 7 reveals, 879 or 51 percent of the degrees were awarded in the basic-science-related biology programs, with the next highest category being environmental sciences with 238 degrees awarded or 14 percent of all bioscience-related degrees. Chemistry and material sciences also demonstrated a large share of total bioscience-related degrees, representing 18.8 percent of all degrees.

Table 7: Arizona Bioscience-Related Degrees, 2000–2001

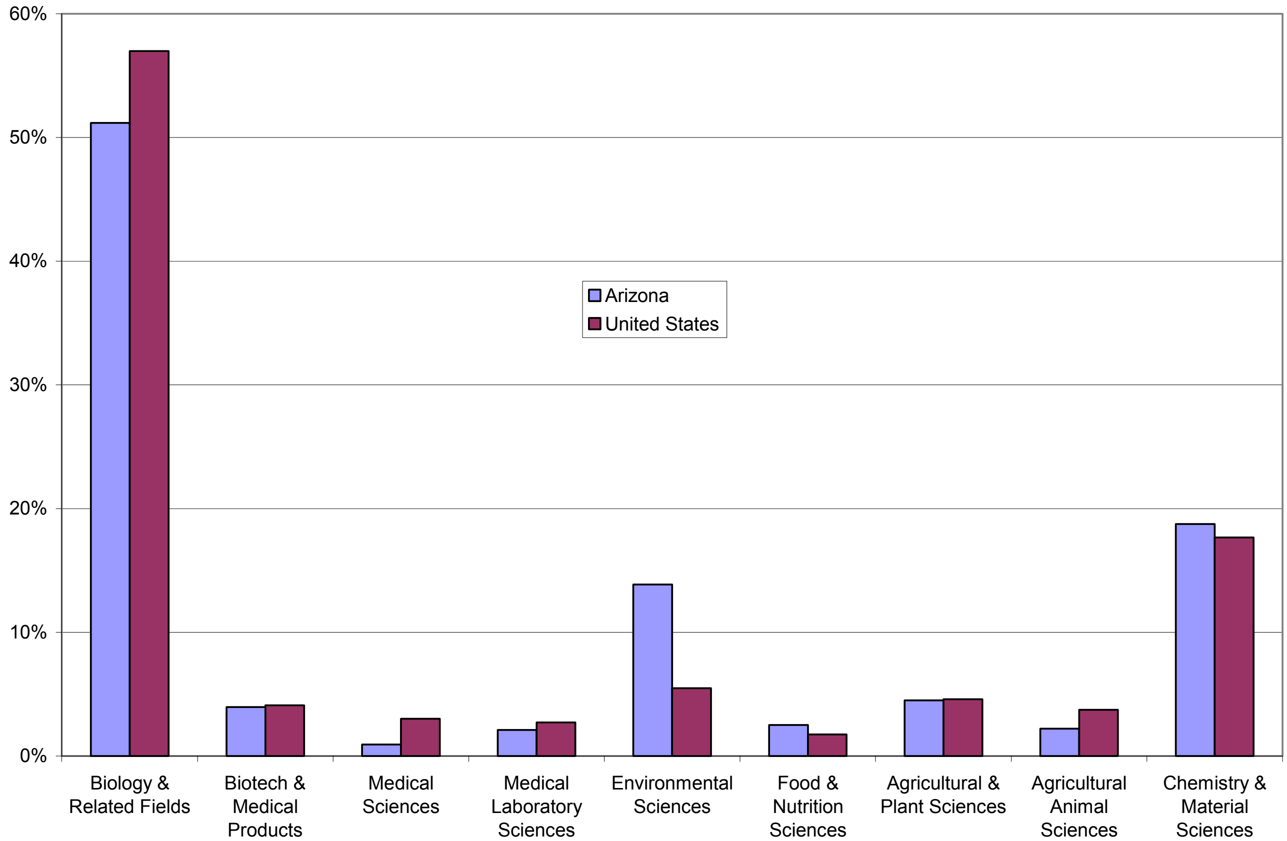
Categories of Bioscience Degrees in Non-clinical Care Programs	Total Number of Degrees Awarded	Percent of Total Arizona Bioscience Degrees
Total Bioscience-Related Degrees	1,717	n.a
Biology & Related Fields	879	51.2%
Biotech & Medical Products	68	4.0%
Medical Sciences	16	0.9%
Medical Laboratory Sciences	36	2.1%
Environmental Sciences	238	13.9%
Food & Nutrition Sciences	43	2.5%
Agricultural & Plant Sciences	77	4.5%
Agricultural Animal Sciences	38	2.2%
Chemistry & Material Sciences	322	18.8%

Arizona stands out in the percentage of degrees awarded in environmental sciences, but is well below the nation in medical science degrees awarded. In the distribution of bioscience degrees, Arizona is more than double the national share in environmental sciences, but only one-third of the national level of medical science degrees. Arizona also has slightly lower shares of degrees in biology-related sciences and animal sciences (Table 8 and Figure 5).

Table 8: Distribution of Bioscience-Related Degrees in Arizona and the United States

Categories of Bioscience Degrees in Non-clinical Care Programs	Percent of Total Arizona Bioscience Degrees	Percent of Total US Bioscience Degrees
Biology & Related Fields	51.2%	57.0%
Biotech & Medical Products	4.0%	4.1%
Medical Sciences	0.9%	3.0%
Medical Laboratory Sciences	2.1%	2.7%
Environmental Sciences	13.9%	5.5%
Food & Nutrition Sciences	2.5%	1.8%
Agricultural & Plant Sciences	4.5%	4.6%
Agricultural Animal Sciences	2.2%	3.7%
Chemistry & Material Sciences	18.8%	17.7%

Figure 5: Distribution of Bioscience-Related Degrees in Arizona and the United States, 2000–2001

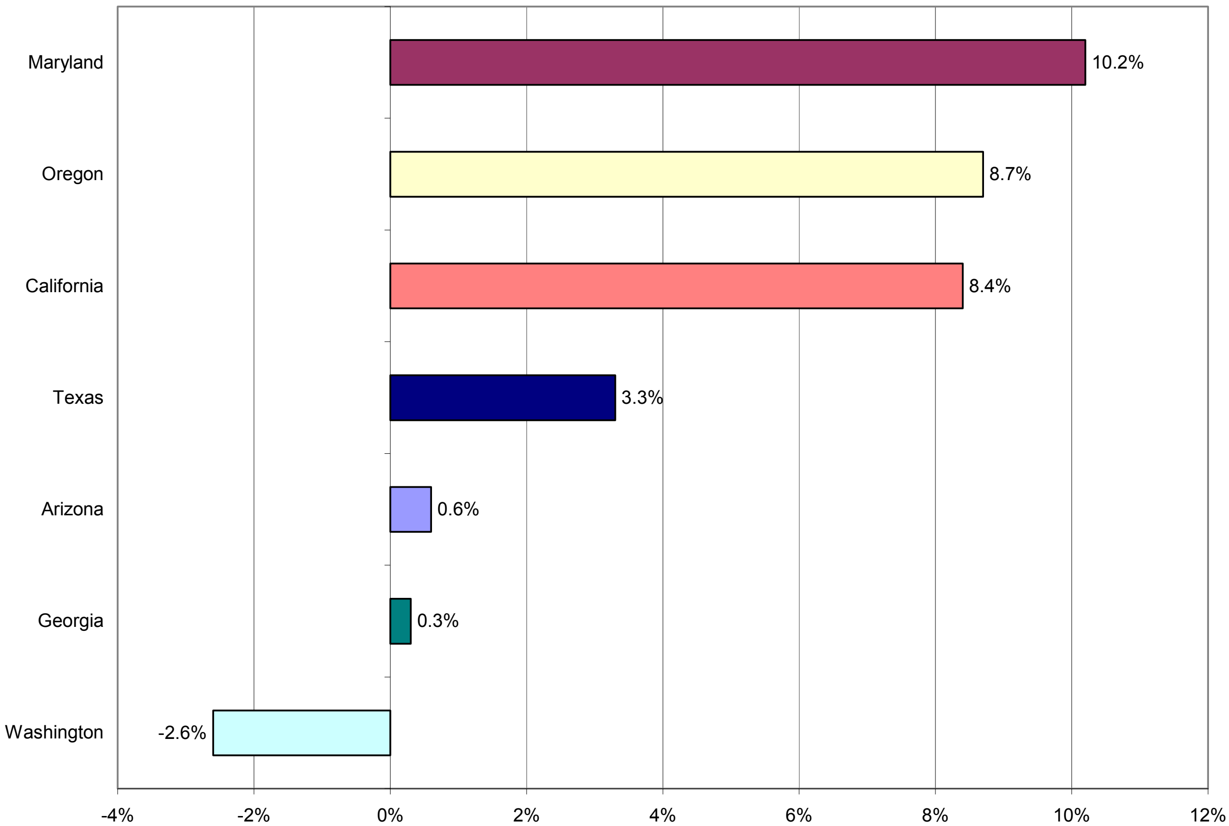


Overall, the total number of bioscience-related degrees in Arizona declined by 264 or 13.3 percent between the 1995–1996 and the 2000–2001 school years (Table 9 and Figure 6). Similarly, all of the benchmark states recorded declines as well. The decline in Arizona, however, was slightly less than the national average decline of 13.9 percent. Relative to the U.S. growth rate, many of the benchmark states, including Arizona, outperformed the national average. Arizona was slightly above the national trend.

Table 9: Total Bioscience-Related Degrees Awarded, 1995–1996 to 2000–2001

	Degrees Awarded 1995/1996 to 2000/2001
United States	-13.9%
Arizona	-13.3%
California	-5.5%
Georgia	-13.6%
Maryland	-3.7%
Oregon	-5.2%
Texas	-10.6%
Washington	-16.5%

Figure 6: Percent Change of Bioscience-Related Degrees Relative to the United States, 1995–1996 to 2000–2001



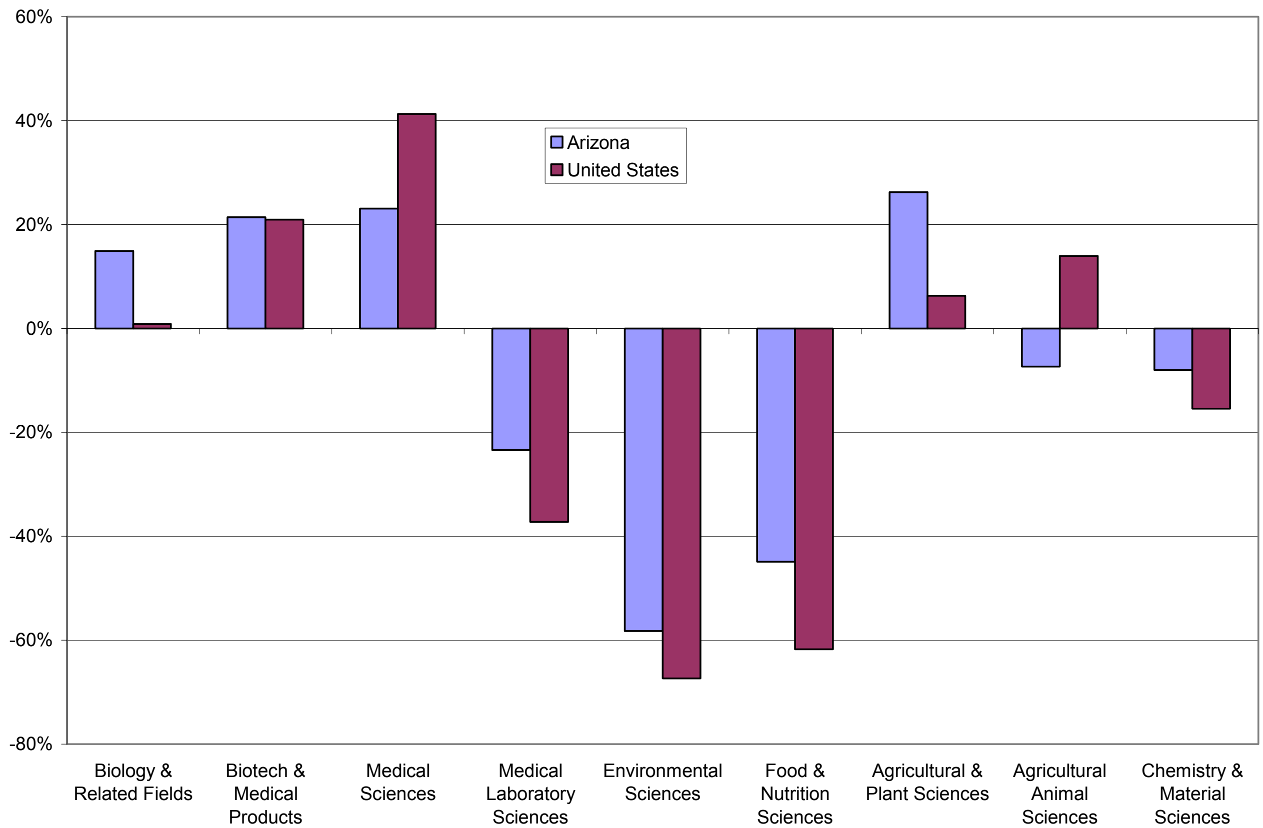
Arizona enjoyed strong growth in degrees awarded in biology-related fields, biotech and medical products, and agricultural and plant sciences. In biology-related fields, Arizona grew by 14.9 percent, well outpacing the national gain of 0.9 percent (Table 10). In biotech and medical products, Arizona grew by 21.4 percent, comparable to U.S. growth of 20.9 percent, while agricultural and plant sciences leaped in Arizona by 26.2 percent, well in excess of U.S. growth of 6.3 percent.

Table 10: Bioscience-Related Degrees Awarded between 1995–1996 to 2000–2001

Categories of Bioscience Degrees in Non-clinical Care Programs	AZ Percent Change in Degrees Awarded 1995/1996 to 2000/2001	US Percent Change in Degrees Awarded 1995/1996 to 2000/2001
Biology & Related Fields	14.9%	0.9%
Biotech & Medical Products	21.4%	20.9%
Medical Sciences	23.1%	41.3%
Medical Laboratory Sciences	-23.4%	-37.2%
Environmental Sciences	-58.2%	-67.4%
Food & Nutrition Sciences	-44.9%	-61.8%
Agricultural & Plant Sciences	26.2%	6.3%
Agricultural Animal Sciences	-7.3%	14.0%
Chemistry & Material Sciences	-8.0%	-15.4%

The fields responsible for the overall declines in Arizona in bioscience-related degrees were medical laboratory sciences, environmental sciences, food and nutrition sciences, agricultural animal sciences, and chemistry and material sciences. Arizona's declines were in keeping with the general declining U.S. trends for medical laboratory sciences, environmental sciences, food and nutritional sciences, and chemistry and material sciences. However, in each degree category, Arizona declined at a *slower rate* than the national average. Agricultural animal sciences was the only category in which Arizona experienced a decline while, at the national level, the number of degrees awarded actually rose (Figure 7).

Figure 7: Bioscience-Related Degrees Awarded for Arizona and the United States, 1995–1996 to 2000–2001



Across each level of bioscience degrees granted—associate's, bachelor's, master's, and doctoral—Arizona declined in degrees awarded. The decline was particularly steep in associate degrees awarded at 64.5 percent, dropping at a much faster rate than the national decline of 29.5 percent (Table 11). This decline reflects the drop in environmental, medical laboratory, and food and nutrition sciences, but also the fact that students pursuing biology degrees often will earn only a general associate's degree and continue on to four-year degree programs. Arizona's decline in doctoral degrees also exceeded the U.S. loss, falling 22.5 percent compared with the national decline of 8.7 percent. While Arizona fell in total number of bachelor's degrees in bioscience-related fields, the decline of 5.2 percent was less severe than the national decline of 10.0 percent; while for master's degrees, Arizona and the United States were comparable in their declines.

Relative to the benchmark states, the steep decline in associate bioscience degrees recorded in Arizona also was felt in several other states, such as Georgia, Oregon, and Washington. Interestingly, California realized an increase.

Table 11: Total Bioscience-Related Degrees Awarded, 1995–1996 to 2000–2001

	Percent Change in Bioscience-Related Degrees Awarded 1995/1996 to 2000/2001			
	Associate's	Bachelor's	Master's	Doctorate
United States	-29.5%	-10.0%	-23.6%	-8.7%
Arizona	-64.5%	-5.2%	-26.0%	-22.5%
California	13.7%	-8.2%	-10.8%	-6.2%
Georgia	-71.4%	-10.6%	-15.5%	1.9%
Maryland	-72.2%	0.3%	-9.7%	-2.3%
Oregon	-61.6%	6.6%	-40.5%	-13.1%
Texas	-18.0%	-10.0%	-18.1%	-10.9%
Washington	-82.8%	-7.6%	-25.1%	0.5%

Bioscience Developments Throughout the Educational Pipeline

To gain a sense of Arizona's position in supplying bioscience workers, it is useful to consider the range of activities and recent programmatic developments taking place throughout the educational pipeline.

K-12 Supply-Side Factors

The biosciences comprise highly technical fields typically requiring some level of postsecondary education. Nevertheless, the K-12 education level plays a critical role in preparing students for the demanding technical nature of bioscience curricula.

There are clear signs that Arizona has a problem with this initial step in the educational pipeline.

The number of students advancing from high school to postsecondary education is lagging in Arizona. A Governor's Task Force on Higher Education reported in December 2000 in *Arizona at Risk: An Urgent Call to Action* that

- From 1997 to 1999, the percentage of 18- to 24-year-olds in the United States who were high school graduates averaged 85.5 percent. The figure in Arizona was 75 percent, and the state ranked 49th out of 50 on this measure.
- Of all U.S. public and private high school graduates in 1998, 57.2 percent enrolled in college in the fall of 1998. In Arizona, this figure was 45 percent, placing the state near the bottom at 47th out of 50.

In an effort to improve the quality of K-12 education in Arizona, significant focus has been placed on standardized testing in past years, including an Arizona law that requires the Arizona

Board of Education to develop competency tests in reading, writing, and mathematics that students must pass to graduate from high school.

In the spring of 1999, the first of these exams was administered to approximately 50,000 Arizona high school sophomores. Eighty-eight percent of the students failed the math portion of the test; and 92 percent failed at least one of the three sections of the test.

Interviews with postsecondary faculty and administrators suggest that not only are students unprepared to handle college-level scientific courses, but high school teachers are not trained to instruct students in the fundamentals of molecular biology and other key preparatory biology-related courses.

Although beyond the scope of this strategic analysis, significant improvements must be made in the K-12 system if Arizona's youth are to become the bioscience workers of tomorrow. Proposition 301 funding has provided a new revenue stream in an attempt to make significant improvements in the quality of K-12 education. Seventy percent of the Proposition 301 funding has been allocated to K-12 education in which

- Forty percent must be used for "teacher compensation increases based on performance"
- Twenty percent must be used for "teacher base salary increases"
- Forty percent must be used for "maintenance and operations purposes," which may include teacher compensation increases.

However, none of these dollars have been allocated specifically to math and science education.

Attention has been given to revamping some of the technical education curriculum over the past several years in an effort to ensure its applicability to industrial needs. For instance, the Arizona Department of Education, Career and Technical Education Division, recently revised the allied health services program to more accurately reflect the changing workforce demands, including the needs of the emerging bioscience industry. In addition to its robust program offering in nursing, it also is designed to prepare individuals for jobs in four additional fields:

- Pharmacy support services
- Laboratory assisting
- Medical imaging support services
- Sports medicine and rehabilitation therapies.

Of particular relevance to this study is the laboratory assisting program. The laboratory assisting program is envisioned as a 2+2+2 program leading from a high school degree to a medical or clinical laboratory technician associate's degree to a clinical laboratory scientist or medical technologist position (which requires, at minimum, a bachelor's degree in medical technology or one of the life sciences). The laboratory assisting program focuses on

- Maintaining standards in the laboratory
- Demonstrating proper application of aseptic techniques in the laboratory
- Conducting the phlebotomy procedure in a laboratory setting
- Applying procedures related to selected specimen collection

- Assuring appropriate laboratory documentation and quality control
- Maintaining laboratory inventory and equipment.

In addition, the Arizona Department of Education, Career and Technical Education Division, also oversees an agriscience program designed to prepare students for employment in various production, sales, and supplier positions related to animal and/or plant sciences. Students completing this program will possess the technical knowledge and skills associated with animal and/or plant production and health, marketing, and sales positions.

However, at this time, the number of schools offering this type of training is quite small. In the allied health field, other than nursing, only 17 schools offered training in the four programs in 2002. It is unclear, since the program is so new, whether more than just a few schools will be able to offer the laboratory assisting program. This is due primarily to a lack of resources, both in terms of faculty and equipment. Some of the school districts, particularly in the rural areas, are seeking partnerships with the local community colleges to provide the training. However, articulation agreements with the community colleges have not been fully implemented, which is leading to additional challenges.

It also has proven to be quite difficult to engage industry to be active participants in the K-12 programs. Most of the interaction is limited to student shadowing projects due to issues of quality control and liability. There is a recognition that these relationships need to be established to improve the curriculum training and overall student experience, but it is proving to be a barrier to growth at this time.

One interesting development has been the creation of the **Arizona Bioengineering Collaboration** (ABC), which began in the fall of 2001, as a four-year project sponsored by a grant from the Howard Hughes Medical Institute to the Arizona Science Center. It brings together educators, researchers, and industry scientists and experts to develop and implement a multicomponent educational program to raise the public's awareness of and interest in local developments in bioengineering and technology. Each year, a Design Team, composed of Science Center staff, teachers, and academic and industry scientists select a topic in bioengineering. The Design Team has completed two topics: one on medical and health care (Doctoring DNA) and the other on agricultural biotechnology (GM Foods in My Schoolyard?). One hundred and fourteen teachers have participated in the teacher training workshops, and an estimated 2,000 students have participated in the student curriculum. The first outreach program was introduced in the spring of 2003, and 100 students have since participated. Thousands of visitors to the Science Center have viewed the DNA demonstration, which has been presented at least three times each week since its introduction in the fall of 2002.

In addition to the changes in the technical education curriculum across the state, many individual school districts also are exploring various options to improve math and science education. For example, a bioscience-focused high school in Phoenix is currently in the initial planning stages. To date, the concept of creating a biotech high school in downtown Phoenix has been explored and has received support from the Arizona State University, the University of Arizona, and the City of Phoenix. The current concept calls for transforming a part of the old Phoenix Union High School campus into the new science-focused facility. The location is nearby the planned headquarters of the Translational Genomics Research Institute and International Genomics Consortium. The concept for the biotech high school is rooted in the belief that the program will engage students' interest in the health sciences at an early age and supplement their learning experiences through interactions with nearby health and research centers, ultimately serving to bolster workforce shortages while contributing to the advancement of Arizona biosciences.

Community Colleges Supply-Side Factors

Arizona has one of the largest community college systems in the nation, which often serves as a national model of excellence. Community colleges in Arizona play a number of key roles in education and workforce development:

- Preparing students to go on to a four-year degree program by giving them an initial college experience along with remedial courses. The college courses provided by Arizona community colleges are typically developed in concert with the four-year degree programs to ensure that they articulate seamlessly
- Offering students terminal associate's degrees that are career oriented and enable students to gain the competency and technical expertise to pursue a specific career track upon graduation
- Providing certificates and additional career-oriented training for postbaccalaureate students who have completed more general bachelor's degree programs, but need to strengthen their hands-on technical skills
- Providing customized training courses in partnership with existing companies for skill upgrading through the Centers for Workforce Development found across community colleges in Arizona.

Community colleges in Arizona play a major role in the allied health field, which trains nurses, therapists, radiologists, and other direct clinical care providers. These activities, however, fall outside the scope of this study.

In the nonclinical care side of the biosciences, the role of community colleges has tended to be more limited, primarily serving to provide lower level science courses for students who go on to four-year degree programs. This role should not be minimized. Community colleges are shouldering a major share of the introductory and sophomore-level science courses taken by undergraduates in Arizona.

One area of bioscience development at the community college level is in career programs for laboratory technicians. While community colleges in Arizona have not been involved in medical technology programs in recent years, they are beginning to step up in other laboratory-related career courses. Recently, two community colleges—Pima Community College and Phoenix College—have been moving forward toward offering an associate's degree in histology to provide qualified workers able to handle and prepare tests of tissue specimens for both hospitals and private industry. The Pima Community College program has its first class this fall, while Phoenix College is getting ready to pilot its program.

Example of a Healthcare Lab Career Program at the Community College Level:

Pima Community College Histology Program

- The program is geared toward training students for careers as histologic technicians.
- The program includes courses designed to provide students with competency and technical expertise with laboratory protocols in nuclear and cytoplasmic staining, immunohistochemistry, enzyme histochemistry, and electron microscopy.
- The program was created through consultation with an industrial advisory committee to meet area workforce demands. In an effort to ensure close interaction with industry, the program also includes a required internship.

Other emerging efforts are also taking place in training bioscience research technicians. Mesa Community College has completed its first year of a new biotechnology associate degree program, and Glendale Community College is actively developing its own biotechnology associate degree program.

Agricultural bioscience is another area where community colleges have begun to fill key career technical education roles, especially in more rural communities. Yavapai College has a growing program focused on greenhouse and fisheries/ aquaculture, which has a successful track record in placing students in jobs. Arizona Western College has two extensive and unique 2+2 programs in environmental science and agricultural systems management that are completely self-contained in Yuma in partnership with both Northern Arizona University and the University of Arizona.

In postbaccalaureate activities, a new program is offered by Gateway Community College focused on training clinical research coordinators, who are essential for clinical trials and other clinical research activities. Typical students for this program would be nurses or others involved in clinical care delivery seeking to be involved in supporting clinical trials.

Interestingly, a focused effort in biomedical devices is absent from community college activities. It is true, however, that community colleges are actively involved in training students for careers in electronics and manufacturing, who often are or become employees of medical device manufacturers.

Four-Year Degree Level

The three state universities, University of Arizona, Arizona State University, and Northern Arizona University, all have large undergraduate programs in the biological sciences. All three are broad-based programs spanning environmental, micro-biological, and molecular sciences. In addition, all of the programs are becoming more involved in teaching the techniques in biotechnology, genetic engineering, microbiology, cell biology, and mathematical analysis of genomes.

Example of Career Lab Program at the Community College Level:

Mesa Community College Biotechnology Associate of Applied Science

- The program is geared toward training students for careers as technical assistants in bioscience laboratories.
- Program includes courses designed to provide students with competency and technical expertise with state-of-the-art laboratory protocols in molecular biology, microbiology, biochemistry, cell biology and other key fields of bioscience, as well as biosafety.
- Program also includes a capstone internship.

Example of Agriculture Bioscience Program at the Community College:

Yavapai College Program in Agricultural Technology Management

- The program is geared toward training students for careers in greenhouses and fisheries, with a hands-on learning environment involved in growing and fish breeding.
- New lab facility will enable more advanced courses in tissue culture, high-end chemistry and sterilization needed for in vitro techniques.
- Growing program with 50 students at any one time and a significant waiting list. Excellent record of job placement.

Unique Partnerships in Yuma, Arizona

Arizona Western College has been able to develop two unique 2+2 programs with four-year institutions within the state in order to meet the educational demands for its rural region. For example, Arizona Western College (AWC) and Northern Arizona University-Yuma (NAU-Yuma) offer a collaborative bachelor degree program in environmental sciences, with areas of focus that include ecology, conservation, environmental compliance, and hazardous waste management.

In addition, AWC also offers in partnership with both the University of Arizona (U of A) and NAU-Yuma a bachelor's degree in Agricultural Systems Management. In this program, the degree-granting institution is the U of A. The educational partnerships of AWC, U of A, and NAU-Yuma allow students the opportunity to earn a bachelor's degree in a convenient and affordable manner, thereby meeting the industrial demand for trained workers in the environmental and agricultural fields.

In terms of more specialized degree programs at the bachelor level educating students in laboratory sciences, the long-standing programs have been in medical technology, with one program found at the University of Arizona and the other at Arizona State University. Each of these programs provide comprehensive laboratory experiences for students to qualify as licensed medical technologists. Like their counterparts nationally, these programs tend to attract small numbers of students—in the 10 to 15 range. The University of Arizona is considering disbanding its program because of low enrollment and high costs of maintaining the program.

Another specialized bachelor's degree emphasizing laboratory sciences found in Arizona is the Molecular Biosciences and Biotechnology Program offered at Arizona State University. Along with a rigorous academic curriculum, this program focuses on training students in techniques involved in molecular biology, genetic engineering, microbiology, cell biology, and mathematical analysis of genomes. It also includes a capstone course oriented toward issues in biotechnology, from business to patenting to entrepreneurship to regulatory affairs.

Another way for undergraduate bioscience students to gain laboratory skills is by participating in research activities with faculty. Northern Arizona University places a strong emphasis on experiential learning for biology students with approximately 110 to 120 undergraduates involved annually in research projects with faculty members, plus offering an advanced molecular techniques course every other year. A particularly interesting model is the Undergraduate Biology Research Program (UBRP) at the University of Arizona. UBRP (see text box) is an excellent demonstration of how research experiences at a major research university can be brought to bear on undergraduate education outside of the actual classroom.

In the area of bioengineering, there is a well-established bioengineering undergraduate program at ASU and a newly developing biomedical engineering technology program at DeVry University. The ASU bioengineering program is quite mature and yet still growing, with 400 declared majors and a graduating class of nearly 60 students. This ASU program offers undergraduates eight subspecialty areas such as bioelectrical engineering, biosystems engineering, molecular and cellular engineering, and biomedical imaging engineering. The majority of students in this program subsequently enroll in graduate or medical school programs. The DeVry Biomedical Engineering Technology Program is just being launched and was developed after strong interest expressed by industry. It emphasizes all of the core skills found in

Example of Hands-On Laboratory Program at the Four-Year Degree Level:

Undergraduate Biology Research Program at the University of Arizona

- The Undergraduate Biology Research Program (UBRP) focuses on developing laboratory experience for undergraduates. Started in 1988, the program has expanded by attracting support from the Howard Hughes Medical Institute (HHMI), the National Science Foundation (NSF), and the American Society for Pharmacology and Experimental Therapeutics. The students are expected to spend the summer working full-time in the lab and then part-time throughout the school year. Students are paid for their time in the lab. Faculty sponsors pay half of the UBRP students' wages. UBRP supports approximately 140 University of Arizona undergraduate students per year and includes more than 240 faculty sponsors.

Clinical Lab Sciences Program at Arizona State University

- Trains students across lab science areas of clinical chemistry, hematology, clinical immunology, immunohematology, clinical microbiology. Strong emphasis on GLP involving documentation, following procedures, and biosafety.

Molecular Biosciences & Biotechnology Program at Arizona State University

- Specialized bioscience degree program that emphasizes laboratory techniques, along with a rigorous academic curriculum. Key laboratory techniques include molecular biology, cell biology, genetic engineering, and microbiology. A growing program with 120 declared majors.

electronics engineering, with a strong foundation in biological sciences in order to be involved in product development and manufacturability related to bioinstruments, medical devices, and imaging equipment.

Graduate Degree and Professional Development

At the graduate level, the data on graduates suggest that Arizona is trailing in the biosciences. There clearly is a need for greater resources to support growth in graduate bioscience education in Arizona.

Limited program development activities for bioscience professional degrees are underway. This development is critical as the biosciences move from theory into practice and have to integrate many converging areas of technology. These professional degrees in the biosciences are particularly important to enable existing bioscience professionals to advance in their skills and knowledge.

ASU has a Computational Bioinformatics degree, which is an “elite” program established to address the need for professionals trained in mathematical and computational analyses for the biosciences. It is a terminal two-year master’s program. The University of Arizona, meanwhile, is developing a Professional Master’s Degree Program in Applied Biosciences with a solid foundation of advanced core courses in cell biology, molecular biology, and other key areas, as well as coursework in business fundamentals, project management, and intellectual property law. Northern Arizona University is considering options for a number of master’s level programs in the biosciences, such as a medical physics program through its Applied Master’s in Sciences.

Key Challenges

Overall, the movement by Arizona education to address bioscience career development is just emerging and needs more focused direction. From discussions with faculty and program administrators, a number of key issues were identified.

Financial constraints hold back access to hands-on laboratory facilities. Academic programs across most community colleges and four-year institutions face difficult financial constraints that affect their ability to offer in-depth laboratory instruction necessary to equip their biology students with the hands-on skills needed to work in laboratory or biomanufacturing settings. With recent cost pressures, the ability to create laboratory space is under real threat across public institutions throughout the nation. Already, the lack of funding has required some postsecondary schools to cut back on the number of laboratory courses that they offer and require for graduation due to both the costly nature of the classes and to the shortage of lab space available.

There is a clear lack of clinical laboratory science programs in Arizona. Given the strong demand for healthcare and research laboratory technicians and technologists, it is surprising that so few programs exist in the state and that the University of Arizona medical technology program is under threat of being closed. This area is ripe for creative approaches in Arizona—approaches that are not focused simply on creating more programs, but on the need to create more student interest.

The medical device industry is largely missed by current educational and workforce offerings. It is surprising in Arizona, given the size of its medical device industry, that a more focused effort to address workforce development issues does not exist. This complex area involves addressing the multitude of skill needs of biomedical device companies found in the state and the fact that medical device companies often draw on traditional manufacturing and engineering skill sets. Yet, common issues of regulatory requirements and quality standards for biomedical devices and addressing non-English-speaking workers' needs in skill upgrading seem to be two areas ripe for near-term development.

Despite advances in course articulation, program articulation in the biosciences is being held back, reflecting tensions between learning hands-on skills and basic science knowledge. Arizona is generally very active in promoting articulation between the Community Colleges System and the public universities, as well as a growing number of private universities, such as Midwestern University. However, even with the generally effective processes in place, an uneven pattern of articulation exists at the program level for bioscience programs. There seems to be a tension across the biosciences in Arizona between courses involving students gaining hands-on skills in advanced laboratory techniques and the ability to articulate those courses to a four-year program. Many of the specific hands-on courses simply do not articulate into established bioscience programs found at the four-year level—reflecting the differences between traditional bioscience degrees and bioscience career programs. Arizona may need to consider new types of bioscience bachelor programs at the four-year degree level that can recognize the value of the hands-on bioscience skills curriculum offered at the community college level. Steps to do so will differentiate Arizona from the nation and help address both pipeline issues and career opportunities for community college graduates and undergraduates wishing to pursue careers in the biosciences.

Teacher externships are needed, especially for community colleges. Given the changing skill needs in the biosciences reflecting the advances in research methods and techniques, it is important—especially at the community college level where the emphasis is on teaching, not research—that teacher externships be a regular component of professional development. These teacher externships can involve research institutions along with private sector companies.

Concern about the quality of high school programs should be addressed. Interviews with postsecondary faculty and administrators suggest that not only are students not prepared to handle college-level scientific courses, but high school teachers are not trained to instruct students in the fundamentals of molecular biology and other key preparatory biology-related courses.

Weak connections exist between local bioscience employers and bioscience students in Arizona. Particularly with San Diego being so close, many perceive that working in the bioscience industry means leaving the state. The industry that does exist in Arizona does not seem to be closely aligned with the educational infrastructure. More needs to be done through outreach and internship programs to capture the indigenous student body in the state.

New mechanisms for fostering industry involvement and guidance in bioscience education and workforce development are needed. The partnership between industry and academia needs to be more robust statewide to ensure that academia is meeting the workforce demands of the industry for which it is preparing the students. The relationships need to more systematically address workforce issues such as

- Providing input by businesses on programs and curricula that address training needs
- Gaining bioscience employer support through donated or shared equipment, and providing industry scientists and engineers to help teach courses
- Seeking more business representation and activity on college and university boards
- Encouraging higher education to be more accountable for workforce development
- Developing externships by lending employees to teach classes
- Providing expanded internships and other hands-on training opportunities for students.

Strategic Assessment of Arizona's Strengths, Weaknesses, Opportunities, and Threats

Situational Analysis

Drawing from the completed analyses (including the demand analysis [including survey of bioscience organizations and follow-on interviews], secondary data analysis, and educational inventory analysis), a comprehensive analysis was performed of the overall strengths, weaknesses, opportunities, and threats (SWOT) facing Arizona in developing its biosciences workforce.

This SWOT analysis is much like a business planning process. In preparing its business plans, a company undertakes a similar SWOT analysis, identifying its internal strengths and weaknesses and taking into account and addressing external factors, including markets and opportunities and adverse events and threats. Arizona, for this analysis, was examined much as a business would examine itself.

This SWOT analysis provides a strategic situational assessment of Arizona's position in bioscience workforce development. It should be noted that in some cases perceptions are included in this SWOT, whether accurate or not, since they reflect the climate within which progress can be made in building a bioscience base.

Strengths

Generally, hefty gains are projected in overall employment across research, laboratory technician, manufacturing and production, and management support job functions employed by bioscience organizations in Arizona.

The Battelle survey findings project a 20 percent increase in employment for job functions across the base of bioscience organizations in Arizona. The survey results find total employment in key bioscience job functions—not including clinical care or administrative functions—growing by 1,202 jobs based on responses from 73 bioscience firms representing 65 percent of total bioscience industry employment.

Manufacturing and production is the main occupation found among the major nonclinical-care job functions of bioscience companies in Arizona, and it is expected to experience healthy growth in hires over the next two years.

Based on the Battelle survey of Arizona bioscience companies, the manufacturing and production job function employs 1,502 workers, accounting for one-fourth of all nonclinical-care job positions across the base of Arizona's bioscience industry. The growth rate over the next two years for the manufacturing and production position is expected to be 17 percent or 251 positions. Over 90 percent of bioscience manufacturing and production positions in Arizona, identified through responses to the Battelle survey, are found in the medical device industry. This is not surprising, given that nationally 50 percent of all medical device workers hold manufacturing and production occupations.

Relating to the strength in medical devices found in Arizona, biomedical engineering is a sizable job function and the largest occupational specialization in Arizona; but, its job growth prospects are just moderate over the next two years.

Secondary occupational data reveal that Arizona has an 85 percent higher concentration level of biomedical engineers than found nationally. The Battelle survey reveals that the product R&D engineer job function employs 385 in Arizona with 30 new hires this past year and an expected 34 new hires from 2003 to 2005 (a 9 percent gain).

Medical laboratory technician is one of the largest job functions in the biosciences and an area of occupational specialization in Arizona with strong demand for hires in the next two years.

Battelle's survey of bioscience companies finds the medical lab technician to be one of the largest job functions across bioscience firms, with employment of 1,272, and the leading area of expected hires over the next two years with 341 from 2003 to 2005, or 27 percent of its existing employment base. Medical lab technicians also have a much higher concentration in Arizona than found nationally, standing 41 percent higher in Arizona based on occupational data collected by federal and state agencies.

The demand for research technicians is highest as a percentage of existing employment.

From 2003 to 2005, the new hires for research technicians are expected to be 47 percent of the existing employment base for that job function, making it the highest demand rate of any job function. Altogether, the responding bioscience organizations expect to add 160 research technician jobs from 2003 to 2005, based on the Battelle survey of bioscience companies.

A major boost in research scientists is expected over the next two years in Arizona.

New hires of research scientists are expected to reach 39 percent of the existing base of that job function from 2003 to 2005, adding 132 positions to a base of 342 research scientists, based on responses to the Battelle survey of bioscience companies. Much of this gain in research scientists will be postdoctoral workers employed across the research institutions in Arizona.

Despite an overall decline across all bioscience degrees in Arizona, basic biology science-related degrees have experienced strong growth since 1996, outpacing the national average growth and providing an extensive base of students graduating with degrees in biology and related sciences in Arizona.

There were 879 graduates in biology and related sciences across Arizona's postsecondary institutions in 2001. This represents a gain of 15 percent from 1996, well outpacing the national growth in biology and related science graduates of 1 percent from 1996 to 2001. These biology-related degrees include microbiology, cell biology, biochemistry, and other degrees emphasizing basic biological sciences. This robust growth in biology and related science graduates in Arizona also runs against the overall decline in bioscience-related degrees of 14.5 percent in Arizona, led by hefty declines in environmental sciences, medical laboratory sciences, and food and nutrition sciences.

Heightened support for the biosciences is seen in Arizona.

Arizona has embarked on a number of key investments to bolster its position in the biosciences, reflecting a critical political consensus in the state on the importance of the biosciences for the state's quality of life and economic future. So, it is timely to address workforce development.

Competencies in electronics, optics, and information technologies are found in Arizona.

The future development of the biosciences will draw significantly on the convergence of technologies with growing bioscience understandings to deliver new products and services such as innovative new drug delivery approaches, improved diagnostics, home-based medical care, and advanced "smart" medical devices. Arizona's traditional strengths in the physical sciences—particularly in optics, electronics, and information technologies—will be an important complement for the development of the biosciences in the state.

Weaknesses

Key shortfalls exist in filling healthcare laboratory technology positions.

Healthcare laboratory technology is an area with the highest level of vacancies and needed new hires, and yet has low and declining levels of graduates. A recent decision by the University of Arizona to eliminate its medical technology program will only worsen the situation. Arizona also lacks any two-year medical laboratory technician program in its community colleges. This program could provide students the more general skills that are often lacking in technical school graduates. The labor market issue is expected to worsen given the aging of the current med tech workforce and the low numbers of students attracted to the field. This is a national problem, but one that may hit Arizona hard given its focus on health care services.

Workforce development needs for medical device manufacturers and their workers are not well recognized.

The medical device industry nationally is not well recognized in workforce development efforts at the postsecondary level, despite being large and fast growing. While the skill sets required by medical device manufacturers are often more akin to those of other types of manufacturing than highly bioscience related, such as machining, computer-aided design (CAD), electronics, mechanical and electrical engineering, and material sciences, what separates medical device manufacturers are the quality and regulatory standards they face for their products. Arizona can take a more active leadership position by advancing specialized courses and short-term programs that can be helpful in training workers on these quality and regulatory requirements, while also introducing biological concepts that increasingly will be integrated into medical device products. Also, many manufacturing and production workers for medical device companies in Arizona face the challenges of being illiterate in English. English-as-a-Second-Language approaches are needed to help medical device companies in Arizona have a competitive workforce.

Industry leaders are concerned that the availability of qualified research scientists and lab technicians is limited in Arizona, with continued outflow of top graduates to California.

A chicken-and-egg issue is facing Arizona's bioscience industry, particularly in more commercial research and testing and drug development activities: while the current supply of research scientists and lab technicians is sufficient to meet industry demands today, it is inadequate to support future growth over time. For research lab technician positions, demand is driven by academic research institutions, which do not offer well-developed career development paths and more typically employ recent four-year degree graduates who then pursue more graduate or medical training.

Lack of funding for laboratory instructional facilities and continued state cutbacks in higher education undermine the ability of more traditional academic biology programs to keep up with advances in biotechnology techniques and methods.

As found across the benchmark states, most postsecondary biology students are ill-equipped in hands-on skills needed for bioscience research technician positions. Generally no different, Arizona is wrestling with budget cutbacks that make it difficult to operate expensive instructional facilities.

Articulation is not a focused element of new program development in Arizona.

Across most of the new program developments at the community college and bachelor's degree level, there is no strong emphasis on articulation. Arizona has in place one of the more advanced articulation processes across higher education; yet, there are still walls between "academic" and "career" oriented programs that seem artificial in a highly complex technical field like the biosciences. From the limited number of new programs being put in place, articulation is not a major emphasis. So, for instance, the biotech laboratory technician programs at the community college level do not easily articulate into bachelor's degree programs and end up being more terminal in nature, which is a problem when so much emphasis is placed by bioscience organizations on bachelor-level degrees for lab workers in both medical and research settings.

The decline in the level of bioscience master's and doctoral graduates is aggravated by cutbacks in higher education spending.

Across the bioscience fields, Arizona has recorded significant declines in master's graduates and doctoral graduates, falling 30 percent and 22 percent, respectively, from 1996 to 2001. The decline in doctoral graduates is well off the national pace; the nation recorded an 8 percent fall-off compared with 22 percent in Arizona. According to some academic representatives, this decline is not surprising because cutbacks in higher education have limited the availability of funding for graduate students. This decline is of consequence to the development of Arizona's bioscience cluster because graduate students are a key source for postdoctoral workers in research labs, as well as often going into industry or forming their own companies.

Communications and mechanisms for connecting bioscience employers with bioscience educational programs and students are lacking.

Given the emerging nature of the biosciences in Arizona, it is not surprising that there is no focused, coordinated approach for outreach, skills development, and placement of students with bioscience employers. Rather, it falls to individual schools and, more typically, programs and faculty to build this network. Under the present situation, it is difficult for individual bioscience employers to navigate academic institutions and help shape curriculum and program development as well as awareness of career opportunities in the biosciences.

Access to educational opportunities is limited for minority, economically disadvantaged, and underrepresented groups, with gaps in early intervention to prepare these students in K-12 for bioscience fields.

Discussions with educational officials and faculty from across the state revealed that many of the fastest growing populations of students in Arizona are those who have limited exposure to technology-oriented careers—particularly Hispanic students—and that outreach and enrichment programs are insufficient in the early grades to provide meaningful access to leading-edge career development efforts in the postsecondary system.

Concern exists about the quality of high school programs in the biosciences, including the quality of teachers.

The statistics on the poor quality of K-12 education in Arizona clearly reflects on the quality of students being educated and trained at the post-secondary level in the biosciences. In discussions with postsecondary faculty members, especially at the community college level, the general weakness in the quality of students is seen as a critical impediment not only in instructing students, but in attracting students to enroll in bioscience programs.

Another consequence of the lagging quality of K-12 education is that it undermines the ability of bioscience employers to recruit scientists and their families to Arizona.

It is not surprising that families of scientists place a strong emphasis on having access to high-achieving academic K-12 schools for their children. So, the low quality of Arizona's K-12 public schools makes it harder to recruit scientists to Arizona.

Opportunities

Developing articulated bioscience workforce development career pathways that bridge the educational spectrum and utilize existing educational infrastructure.

The demand for bioscience workers across the spectrum of educational requirements calls for creating more seamless career-oriented educational approaches that allow students to pursue their educational focus in a "2+2+2" approach with career opportunities at each stage. This seamless educational approach can effectively ensure that existing infrastructure can be best integrated and gaps filled. For instance, building off the emerging career pathways approach being advanced by Banner Health's Laboratory Sciences of Arizona, opportunities exist for clinical laboratory workers at all levels of education, from high school with some training to community college and bachelor's programs. The challenge is to create the educational bridges that allow students/prospective employees to see how they can seamlessly move through the educational continuum as they seek to advance their careers. Similarly, in medical devices, there is a need for workers across the educational spectrum, but even a less well-developed career pathway across education.

More closely integrating development of medical tech with biotech research technicians.

A particular need in Arizona, given the strong growth of laboratory technicians in both medical and research settings, is more creative linking of bioscience laboratory skills development. Presently, there is a strong momentum in Arizona to develop new programs in biotech laboratory skills development, but a mixed focus on clinical laboratory skills development. Yet, many of the jobs to be found in laboratory skills are in the clinical lab setting, despite a robust growth in research jobs, given the state's high employment in medical care. Finding opportunities to marry the strong skills in conducting and managing laboratory operations found in med tech curricula with the techniques and more advanced, scientific biotech lab programs can create more flexible career options for students and perhaps insulate Arizona's programs from the short-term ups and downs in the labor market.

Fostering closer connections between bioscience employers and educational institutions, involving strong leadership commitments, to develop well-rounded bioscience educational programs and advance broader range of skill mix.

Key to building career pathways and developing new types of programs is to establish close ties between bioscience employers and educational institutions that are sanctioned and encouraged by senior leadership in education and industry. Significant industry involvement is one of the key success factors for bioscience program development identified for the benchmarking analysis. As one program director explained: "Because they work so closely with industry, the students are trained exactly as industry needs them." Moreover, these close ties enable programs to break through the traditional perceptions of degrees required and focus on skills needed for bioscience lab positions, and have led to success in creating more focused career training programs for entry-level lab assistant positions as demonstrated in Baltimore and Berkeley. The challenge for Arizona is to establish these close connections with employers on a more systematic basis across the state and across job functions.

Accelerating new bioscience program developments across the continuum of educational institutions, leveraging new bioscience investments taking place in Arizona.

Simply doing business as usual across Arizona's educational programs will not meet the challenges of bioscience workforce development for the future. Despite signs of innovations across secondary, community college, four-year degree, and graduate programs, overall the progress is slow, marginal, and inconsistent. At the same time, these are exciting times in Arizona for bioscience development. Many new anchor developments are moving forward—some with Proposition 301 funding for research and technology transfer (such as The Translational Genomics Research Institute, AZ BioDesign, and University of Arizona's Biomedical Science and Biotechnology Initiative)—which can offer a means to promote more hands-on experiential skills development. Also, Proposition 301 offers a source of funding for access and workforce development that can be used to promote a broader range of activities to strengthen Arizona's bioscience workforce development efforts.

Positioning bioscience workforce development as an economic development tool.

Arizona seems well positioned to advance a more proactive economic development focus to its bioscience development activities. Given the emerging nature of many segments of the bioscience industry in Arizona, coupled with the major investments ongoing in bioscience research, a proactive approach would be well timed. Emerging and growing bioscience businesses in Arizona need help in meeting their workforce needs, through more customized and focused training activities, particularly tied to the already sizable base of bioscience graduates in the state. In addition, Arizona also has the advantage of being near the state of California, one of the most advanced biotechnology centers of the world. As the base of California companies matures, new types of operations and facility investments will be required, such as the emergence of biomanufacturing, for which Arizona can develop innovative higher education workforce programs to meet the skill needs for staffing these operations in concert with prospective employers. Georgia is a good example of a similar emerging bioscience base and higher educational workforce development efforts to attract new bioscience industry operations to the state.

Leveraging growing presence of postdoctoral bioscience workers in Arizona.

Over the next several years, Arizona will see a major increase in the number of postdoctoral workers helping to advance bioscience research in the state. Most of these postdocs will be recruited from outside of Arizona and typically will be in the state for several years before seeking new employment, often outside of the state. However, this base of postdocs represents a major infusion of talent in the state, which can help contribute to growing Arizona's bioscience industry base. Specialized outreach in entrepreneurial development and orienting these postdocs to industry opportunities in Arizona can tie this highly educated and expert pool of bioscience workers into a longer term advantage for the state.

Threats

A growing number of Arizona bioscience graduates may come from nonresidents with few ties to the state and who are less likely to pursue long-term careers in Arizona.

Arizona universities continue to rise in stature and are becoming attractive choices to students outside of the state. The number of applications from well-qualified non-Arizona students is increasing. At the same time, with a resident student population becoming ever more diverse and with minority, economically disadvantaged, and underrepresented students driving student enrollments, there may be fewer Arizona students pursuing or prepared to undertake studies in the biosciences.

At the same time, California is attracting recent Arizona bioscience graduates to relocate.

Many of the best jobs in the biosciences are found in California, which has one of the largest concentrations of bioscience companies in the world. From interviews with faculty members, it is clear that California attracts many of Arizona's recent graduates in the biosciences, as well as other fields.

Budget cuts are having an impact on higher education.

As in all states in this time of fiscal downturn, Arizona's public higher education institutions are tightening their belts. For the biosciences, this means that traditional academic instructional programs, which increasingly require more advanced laboratory facilities, are facing an inability to expand to meet the needs, if not painful reductions.

Obtaining visas for postdoc workers is difficult.

Arizona is revving up its bioscience research engine at the same time that immigration restrictions on foreign students and workers is tightening, given threats to homeland security. This may pose a problem for research organizations as they seek to quickly ramp up their research activities.

Public perceptions of the biosciences are being limited and not going beyond the headlines of the day.

The biosciences in Arizona have benefited significantly in recent years from the news stories reflecting the opportunities of applying genomics to improving medical treatments and care. However, news headlines also can undermine the biosciences by overemphasizing controversial issues involving cloning and genetically modified foods. A more well-developed public understanding of the biosciences is needed that is based on how the biosciences can improve the quality of life in Arizona and be an important source of quality jobs for Arizona residents.

SUMMARY

As Arizona considers how best to address bioscience workforce development, this strategic assessment can help. The strengths found in Arizona largely reflect the healthy demand for bioscience workers, while the weaknesses point to key gaps in service offerings and more structural problems in Arizona's capabilities to move strategically and proactively to address bioscience workforce needs. The opportunities for Arizona are substantial and reflect the specific circumstances found in Arizona, particularly in addressing how to pursue bioscience education and training programs in light of industry demand, ongoing investments, and economic development strategies. Finally, the threats, while significant, may reflect more about the past than the future, if Arizona can effectively address the key elements of developing its bioscience cluster.

Bioscience Workforce Development Benchmarking Analysis for the State of Arizona

INTRODUCTION

As states and regions embrace bioscience development as a key targeted economic driver, they begin to develop initiatives designed to expand and improve bioscience workforce training and education. This section presents the results of a benchmarking analysis of selected state efforts in advancing bioscience development.

Purpose of Benchmarking

Benchmarking, commonly undertaken in the corporate and financial communities as a way of improving efficiency and calibrating performance, is equally as important in planning for technology-led economic development. Benchmarking identifies, analyzes, and draws useful lessons from the practices of regions and institutions that are generally comparable along relevant strategic dimensions.

For technology-based workforce development, benchmarking can be particularly helpful in these activities:

- **Isolating strategic issues.** To design a strategy for technology workforce development, a region or institution must understand what its key choices are and how various potential uses of resources trade against each other. Examining how competing entities have positioned themselves can provide insight into what strategic choices must be made in view of the home region/institution's strengths and weaknesses and the opportunities and threats posed by the broader marketplace.
- **Figuring out what works.** There is no point in reinventing the wheel. Strategies and initiatives that have worked in other regions/organizations facing similar challenges often can be adapted to local conditions, avoiding the risks of investing in entirely untried approaches unless the situation explicitly requires that.

The Benchmarking Set

Rather than simply creating a listing or catalog of state programs in the biosciences, this benchmarking effort sought to gain a more strategic understanding of state efforts in bioscience workforce development. The goal was to identify excellent programs as well as examine how the selected benchmark states are addressing key program and organizational issues in bioscience workforce development.

This called for more in-depth case studies to be developed on specific states. The selection of the benchmark states needed to reflect a balance: on the one hand, states should be *leaders* in overall bioscience development that Arizona can aspire to; while on the other hand, they should be *peers* and facing similar issues to Arizona to help inform key choices and approaches. Another dimension specific to the biosciences is the role of federally supported efforts in bioscience workforce development. The National Science Foundation through its Advanced

Technology Education program has established a national center of excellence in biotechnology workforce development known as Bio-Link, which involves a collaboration of specific community college programs found across the nation. Part of this benchmarking exercise involved learning about these federally supported programs, as well as how these individual programs fit within a broader regional and state context.

Based on guidance from the Project Advisory Group, a set of states was selected for benchmarking and, in several of these states, specific regions were selected for more focused reviews.

- California, one "leader" state benchmark, is generally recognized as a global center for the growing biotechnology industry. One-third of all U.S. publicly owned biotechnology companies (e.g., research and testing, one segment of Arizona's bioscience cluster) are located in California, as well as an estimated one-third of the biotechnology workers in the United States. The San Francisco and San Diego regions each have a community college associated with the Bio-Link program, which is headquartered in San Francisco.
- Maryland, another "leader" state benchmark, has a more recently emerging bioscience cluster. Maryland's bioscience cluster grew from 53 bioscience firms in 1991 to 258 in recent years. Moreover, Maryland was the first state to put in place a comprehensive biotechnology strategy, which dates back to the early 1990s.
- Texas was one of four peer states identified, with three communities of particular interest: Austin, Houston, and San Antonio. Texas is well known for its world-class academic health centers, and its bioscience industry is growing and an active focus of economic development initiatives. Furthermore, Austin is home to one of the Bio-Link associated community colleges.
- Georgia, another peer state, is emerging as the Southeast's leading bioscience state, bolstered by a focused investment strategy through the Georgia Research Alliance and other state initiatives.
- Oregon, another peer state, has enjoyed robust growth in its academic health center and has a base of innovative biomedical product companies similar to Arizona.
- Added by Battelle as another peer state, Washington is one of the emerging bioscience states in the nation, led by a strong concentration in the Seattle region around the University of Washington.

This analysis does not represent these jurisdictions as the only ones that Arizona need worry about, nor as the only ones where effective and creative programs are under way. However, these benchmarks are sufficient to survey for a snapshot of what Arizona faces as it designs its strategy.

Defining the Focus on Bioscience Workforce Development

The focus in this benchmarking activity was to explore the key issues and emerging best practices for bioscience workforce development. It included those specific certificate and degree programs focused on bioscience-career-specific and workforce-related skills development.

In reviewing state efforts, the focus was not on efforts to promote more traditional educational activities in the biosciences, such as postsecondary degrees in biological sciences, except as they relate to programs and initiatives designed to provide students with relevant workplace skills needed to become bioscience workers.

While clinical lab sciences is an important occupational area for bioscience workforce development, it is a more mature and developed area with its own licensing and accrediting requirements at a national level. Therefore, attention was not focused on these more occupational-based programs unless they are being leveraged to develop broader trained bioscience workers.

Structure of the Analysis

This analysis is based on detailed case studies of benchmark states that provide summaries of the states' bioscience workforce activities along key "system" issues, as well as presenting detailed reviews of leading program efforts based on interviews conducted by Battelle staff. These case studies are found in Appendix E to this report.

The following key findings are distilled from these benchmark case studies:

- State experiences in bioscience workforce development efforts
- Leading program efforts found across the continuum of education efforts
- Lessons learned, including key success factors, barriers to overcome, and strategic issues shaping bioscience workforce development.

State Experiences in Bioscience Workforce Development Efforts

This analysis first considered what a state must do, systemically, to promote the production of a well-qualified bioscience workforce. Key issues and typical practices found across states, as well as leading examples of approaches, were identified.

Across each of the benchmarks, a number of specific dimensions were examined. These key dimensions that address how bioscience programs are designed, organized, and implemented included

- Use of strategic assessments of bioscience workforce needs
- Types of students served
- Extent of program articulation and program linkages
- Approach to development of curriculum
- Role of internships and other experiential learning activities
- Coordinated program development (including teacher training, labs, and curriculum)
- Leading program efforts found across the continuum of education.

Use of Strategic Assessments of Bioscience Workforce Needs

As states move forward with bioscience workforce initiatives, it is expected that a key tool for guiding their activities would be a comprehensive and ongoing assessment of bioscience workforce needs. With the exception of California and, perhaps on a more skill-focused basis, Washington State, this is not the case.

Key Issues and Typical Practice:

Across nearly all of the benchmark states—including a leading state such as Maryland—programs are relying on interactions with limited numbers of specific bioscience employers, often only one or two key firms, to plan and develop their programs. For instance, Austin Community College's (ACC's) Biotech Program is highly structured to meet the needs of Ambion, Inc.; while Maryland's Montgomery College Biotech Program has regular but informal contact with key lab managers along the I-270 corridor, where two-thirds of the state's bioscience firms are located, to help it decide focus of its efforts (although, when originally designed, it had an industry advisory group of the leading firms).

States and regions use the more broad-based Occupational Employment Statistics Survey forecasts developed by each state's labor market information office using economic fore-cast models, rather than specific surveys of employers. These forecasts offer little in the way of understanding skill needs.

Leading Examples of Assessing Workforce Needs:

A key function of California's regional Biotechnology Centers, which are part of the California Community College Applied Biological Technologies Initiative, is to collect information from bioscience firms through a combination of surveys and direct employer involvement. The Central Coast Biotechnology Center, for example, which is located at Ventura College, conducted a biotechnology workforce census in 1998. The survey collected data on the characteristics of the bioscience companies in the region, the education and specific knowledge skills required of entry-level workers, skills of current workforce needing upgrading, availability of training programs and preferred training delivery methods, and projected hiring needs.

Washington State has recently undergone an extensive needs assessment of the bioscience industry. A task force of community colleges, labor, businesses, universities, and K-12 schools, through funding from the state of Washington's Workforce Develop-ment Fund, created the skill standards guideline for the state targeting two areas: (1) research, development, and manufacturing and (2) regulatory affairs and clinical trials. This initiative has helped to validate existing programs and encourage new ones to begin. The study also helped to solidify working relationships between and across educational institutions and industry. Though programs are developed by each insti-tution on its own, the project has helped to ensure that programs are cohesive and relate to one another.

Types of Students Served

As many bioscience workforce programs are put in place, especially at the community college level, a strong orientation is expected across these programs to serve high school graduates moving along the educational pipeline connecting high schools, community colleges, and four-year schools. This orientation has not proven true.

Key Issues and Typical Situation:

Typically, students served by community college associate in arts (A.A.) degree and certificate programs for bioresearch lab technicians and biomanufacturing are ***predominantly those with***

bachelor's degrees in the sciences and working professionals seeking to enter or to advance in bioscience occupations.

Montgomery College in Maryland had to reformat its biotech program completely to focus on evening hours after a near-death experience at its founding when it was oriented to work with high school students. The majority of Austin Community College biotech students also are coming from the existing workforce, though it is actively seeking to change this scenario through early recruitment programs with high school and even junior high students.

These A.A. degrees and certificate programs at community colleges are attractive to those with bachelor's degrees because, unlike most four-year biology programs, they emphasize the specific laboratory skills needed by biotechnology companies. Even in the most advanced biotechnology communities, four-year biology programs lack this emphasis. The San Diego Workforce Partnership in its 2002 strategic plan for bioscience workforce development recommended that "the University of California at San Diego and San Diego State University should incorporate more laboratory skills into their curricula."

There is also a question of whether bioscience employers will hire two-year degree students because of both an oversupply of four-year degree bioscience graduates and bioscience firms' lack of knowledge of two-year degree programs. In Maryland, a recent survey by MdBio identified the degree level for 9,500 employees working in bioscience companies. Of that total, less than 500 current employees had A.A. degrees. Similarly in Georgia, the University of Georgia System's Intellectual Capital Partnership Program estimates that 65 to 70 percent of Georgia's life science workforce has or needs a bachelor's degree to qualify for job openings. Therefore, institutions in the University of Georgia System are encouraged to offer certificate programs, when possible, in addition to full degree programs. And, the University of California (UC) San Diego Extension program is finding that the real need in the San Diego region is for people with bachelor's or master's degrees, rather than Ph.D.'s or A.A. degrees.

A key factor affecting the demand for bioscience workers at different levels of education is the types of activities of local bioscience bases. In California, as firms move more into manufacturing biological therapeutics, there is an increased openness to hiring A.A. and even vocational tech-trained students for more predictable and repetitive biomanufacturing activities. Battelle, in its work in St. Louis, has found this to be true there as well.

However, another key factor shaping employer requirements may be an awareness of the quality of the non-bachelor's degree programs in meeting their workforce needs. This issue of perception can be overcome, but is often a battle that must be waged employer by employer. Two "best practices" described below—the BioTechnical Institute of Maryland (BTI) and the Berkeley Biotechnology Education, Inc. (BBEI)—have successfully overcome this resistance. To do so, however, these small-scale initiatives required champions from the bioscience employer community willing to think "outside the box."

Extent of Program Articulation and Program Linkages

Bioscience workforce development, because of the advanced technical nature of its skill needs, would be expected to have a broad reach across the educational continuum, calling for more programs of articulation and program linkage.

Key Issues and Typical Practice:

Program-related articulation is important for the biosciences. As community colleges play an important role in providing critical bioscience skills development across states, many bioscience organizations still require the theoretical coursework associated with bachelor-level degrees. However, even among the leader states of Maryland and California, an uneven pattern of articulation exists at the program level. Many of the specific hands-on courses simply do not articulate into established bioscience programs found at the four-year level—reflecting the differences between traditional bioscience degrees and bioscience career programs. For instance, the core bioscience workforce programs found at the City College of San Francisco articulate only with the California State University (CSU), not the University of California.

It is critical to ensure that students earning their first degree in an A.A. biotech program also can be positioned seamlessly into a four-year program without losing considerable coursework and time.

Successful program articulation in bioscience career education reaching to the bachelor's degree level appears to call for new types of bioscience bachelor's degree programs at the four-year level that can recognize the value of the hands-on bioscience skills curriculum offered at the community college level, as suggested by the leading examples of articulation identified here.

Leading Examples of Articulation:

At the level of A.A. to bachelor's degree articulation, two excellent examples include

- Strong articulation of A.A. biotech degrees from Maryland community colleges with a new bachelor of science degree in molecular biology, biochemistry, and bioinformatics "MB3" program at Towson State and with Frostburg State's new biotechnology concentration in its traditional biology degree program. Weak articulation at flagship undergraduate biology programs at University of Maryland College Park and Baltimore County.
- Seamless articulation between Houston's Montgomery College Biotech Institute Biotech Program (with its specialized "skills" courses in cell culture, laboratory methods, and laboratory instrumentation) and University of Houston's B.S. in biotechnology.

At the high school to A.A. level of articulation, where there are fewer examples, Austin Community College is building strong program linkages between high schools and the community college, including developing an "Early College Start" that allows students to take ACC courses that can count toward their high school graduation requirements and having an intro biotech course taught in high schools that counts toward ACC credit.

Approach to Development of Curriculum

Given the technical nature of bioscience careers and the establishment of Bio-Link as a national resource to newly forming bioscience workforce programs that offers a clearinghouse on curricula, one would expect strong orientation to standardization and re-use of curricula. But, this is not the case across the benchmark states.

Key Issues and Typical Practice:

The variation in curricula and the need for programs to customize rather than standardize what is taught across courses reflect the state of the bioscience industry. Unlike many information technology occupations (and even clinical laboratory occupations found in hospitals and medical labs) where certification is at the national level, biotech lab technicians, biomanufacturing, ag biotech, and biomedical engineering lack national certifications. Furthermore, the bioscience cluster includes many industry segments such as research and testing, drugs and pharmaceuticals, medical devices, and agricultural biotechnology.

This lack of standardization reflects, in part, the emerging nature and diversity of approaches found in the biosciences. It also may reflect the young nature of bioscience companies.

Given this lack of standardization in defining skills and techniques, it is not surprising that the most universal success factor mentioned across the variety of programs interviewed for this benchmarking analysis is to have strong involvement of local industry in defining the curriculum, and often to have industry involved in providing instruction.

While a need may exist at the national level to help the bioscience industry better articulate common needs and skill requirements, what appears particularly important at a state or regional level is to have resources available to support continual development of curriculum to keep up not only with advances in the field of bioscience, but with the mix and maturity of local bioscience industry that needs to be accommodated in the curriculum in order for students to be well-received as prospective employees.

Leading Examples of Curriculum Development:

Across the levels of post-secondary education, California has one of the more robust, focused efforts in supporting bioscience curricula. While constantly seeking to find ways to share and leverage across individual institutions, California also ensures that specific schools have resources available to keep their curricula current.

The California State University Program for Education and Research in Biotechnology provides grants of up to $15,000 to support the development of curricula, workshops, and short courses. Greatest consideration is given to projects that are multidisciplinary and multicampus and that promote academic industry linkages.

The California Community College Applied Biological Technologies Initiative (Biotech Initiative) through its regional centers has developed a mechanism for developing and supporting curricula and new programs across a group of institutions.

Role of Internships and Other Experiential Learning Activities

Experiential learning is often heralded as a means of ensuring that students gain real-world experience sought by future employers. It also addresses "brain drain" by establishing relationships between students and local industry, which often lead to future job offers.

Key Issues and Typical Practice:

For bioscience positions, especially in industry, internships are often difficult to put in place. First, many bioscience companies are small and do not have the time to accommodate internships. Second, given the regulatory requirements found in industry—including good laboratory practices and good manufacturing practices—it is difficult to have students work as interns unless they have largely completed their courses of study.

A more common way to give students hands-on exposure to laboratory environments is to have them participate in research activities while at school.

Another interesting scenario is that, after acquiring basic laboratory management techniques, students are hired by employers and become "successful noncompleters."

Leading Examples of Internships:

The BioTechnical Institute of Maryland has established internships as an integral component of its program, required for all participants. This program is geared toward preparing high school graduates with limited college work and some work experience to become entry-level lab assistants. BTI provides an intensive nine-week course of study followed by a three-week internship, which often serves as an informal means for employers to determine whether they want to hire the student.

The Georgia Tech/Emory Center for the Engineering of Living Tissue undertakes a broad range of experiential learning activities: first, students serve as mentors for high schools across the Atlanta area; second, it sponsors an undergraduate research scholars program that recruits rising juniors and seniors from Georgia Tech, Emory, and other metro Atlanta colleges and universities for internships in research labs on projects sponsored by graduate student mentors; and third, it helps arrange internships for their graduate students to undertake research at a bioengineering company.

Linkages with Economic Development Efforts of States and Regions

Having a skilled, technology-based workforce is becoming more and more recognized as a central ingredient for supporting and sustaining economic development in today's advanced knowledge-based economy. In the day-to-day world of economic development, a region's capacity to have cutting-edge, effective technology education and workforce development programs is a marketable asset that can make a difference in attracting outside investment and gaining expansion opportunities of existing businesses.

Leading Examples of Linkage with Economic Development:

The Georgia Intellectual Capital Partnership Program (ICAPP) serves as the economic development arm of the University of Georgia System. ICAPP offers employers its Advantage Program, which supports an existing or prospective Georgia company to work with a college or university to design curricula and courses of study to prepare students for specific knowledge jobs at that company. The company must commit to hire each ICAPP graduate participating in the program. Monsanto took advantage of the ICAPP Advantage Program and worked with Augusta State University to develop bioproduction skilled workers, building upon the local expertise in the chemical industry and applying it to the production of a new synthetic growth hormone that increases milk production in cows.

Key Issues and Typical Practice:

The focus of most of the leading programs found across the benchmark states on serving local industry. The integration—if any—with formal economic development is informal and more of a presentation than an active role in day-to-day economic development.

The benchmark state that is more active than others in pursuing technology workforce development as an economic development tool to be packaged with other key incentives and resources is Georgia.

Coordinated Program Development

A key question is whether efficiencies can exist in growing bioscience workforce programs and whether these efforts can reach the scale of a state.

Key Issues and Typical Practice:

Rather than a coordinated system, what is emerging in states, particularly peer states, is a patchwork of programmatic efforts with little scale or coordination. This pattern of development seems to reflect the development of the bioscience industry base, which has some areas of specialization but whose skill needs are not as broad-based as information technology.

Maryland is perhaps the best example of the lack of coordinated program development. Maryland has many leading programs in bioscience workforce development across the educational continuum, including a targeted effort to bring high school graduates into lab assistant positions, active community college programs in biotech lab technicians, some excellent targeted bachelor programs, a diversified and sizable graduate biotech degree program, and professional development courses.

However, each program found at the community college and four-year levels, even across public higher education, is highly independent, with no statewide planning, financial, or coordinating support. Important opportunities, such as a biomanufacturing program in Frederick, Maryland, where a growing number of such facilities are opening, are missed because no strategic plan (even at the community college level) addresses bioscience workforce needs.

The one state that has demonstrated a highly coordinated approach within its different post-secondary systems is California. Each of the main post-secondary systems in California have in place a coordinating body in the biosciences with resources to advance curriculum development, new facilities, linkages with industry, and coordination among its wide number of institutions. Of the 108 California community colleges, 32 offer either a specific course or full program in biotechnology, and another 24 are planning or beginning such courses and programs.

Perhaps the most interesting approach is the establishment in California through the Community College Applied Biological Technologies Initiative of regional centers that serve groups of community colleges by collecting information on employer needs, facilitating partnerships with local high schools and four-year institutions, supporting teacher training and curriculum development, and helping in placement of students.

Washington State also appears to be moving toward a more coordinated approach with the formation of the Northwest Biotechnology/Biomedical Education and Careers Consortium. This consortium is an outgrowth of the Biotechnology/Biomedical Skill Standards Project and is focusing on becoming a clearinghouse of biotechnology career and educational programming throughout the state. The initial emphasis appears to be on curriculum development, articulation, and information sharing.

Leading Program Efforts Found Across the Continuum of Education

To help those in Arizona seeking to establish leading bioscience workforce programs, it is useful to learn about effective programs in other states and key success factors. This discussion is organized by the bioscience workforce programs found at different levels of education:

- Secondary education/career development efforts
- Community college best practices
- Four-year degree level
- Graduate degrees and professional development.

The focus is not on general bioscience-related programs, but on those that are geared specifically to prepare students for bioscience careers.

Secondary Education/Career Development Efforts

Generally, bioscience career efforts at the secondary school level are limited, in large part because of the demanding technical nature of bioscience workforce requirements.

One active area is training high school teachers in more modern biotechnology techniques. For instance, Portland State University runs the Oregon Biotechnology Education Program providing teacher training workshops at both metro Portland and three rural satellites, making mentor teachers available and providing free equipment loans for teachers to use in their classrooms. Approximately 30 teachers are trained annually in this program.

Another growing trend is the use of mobile bioscience labs to train teachers and expose students to hands-on biotechnology techniques. Maryland's MdBioLab in its pilot efforts has had good success in helping rural counties gain exposure to biotechnology, which is now leading to interest in creating specific courses and establishing specific labs in the high schools.

A number of programs, however, stand out as best practice examples of how to link high school students into bioscience careers:

- **Berkeley Biotechnology Education Inc**.—A fully integrated program that involves targeted high school courses in the eleventh and twelfth grades, a paid internship between the two grades, a paid internship between high school and community college, four community college courses, and a paid year-long co-op work experience in industry while in college. The curriculum is developed by joint industry-high school/community college work groups. The program has been highly successful in meeting its objectives. Approximately 95 percent of BBEI students are youths of color and 60 percent are female. All graduates of the certificate program have been offered regular jobs after program completion, and 50 percent of these are continuing their education in A.S. or B.S. programs while employed. Many of the students are the first to graduate high school in their families, and most are the first to attend a post-secondary education institution.
- **BioTechnical Institute of Maryland**—A free-standing organization outside of the high school system, which works primarily with high school graduates on a specific set of skills identified with industry involvement to enable students to have entry-level positions as lab assistants. It is a highly focused 12-week program, with the first nine weeks focused on in-class training and the last three weeks on on-site internships with participating organizations.

The curriculum is very specific, involving clean room practices and techniques in cell culture, laboratory safety and good laboratory practices, cleaning and sterilization, gowning, weights and measurements, laboratory math, introductory animal care, and molecular biology. Since its formation in 1998, 105 graduates have been placed. Currently, approximately 50 to 60 students are trained per year in its laboratory technician program, with an expected placement rate of 80 percent.

BTI and BBEI share the following program elements for success:

- Involving industry champion(s). Often, it is the relationship with a key company—Bayer Corporation in the case of BBEI and Johns Hopkins University Lab/Chesapeake Biologics for BTI—that allows the programs to be established and gain a track record necessary to expand.
- Identifying a specific job niche in which industry can help devise a specific curriculum to allow students to be productive workers.
- Working outside of the traditional high school setting as an independent entity—with an independent budget, ability to raise foundation funds, be more flexible.
- Focusing on support services to students, including mentoring from faculty and business lab coordinators; counseling on careers, job applications, and interviewing; and paid tutoring.
- Having internships and co-op work experience that help students and give industry the opportunity to see students as prospective employees.
- Putting industry priorities up front by addressing real skill shortages, giving industry leadership in setting priorities; giving industry the opportunity to see students as prospective employees, and reducing recruitment and retention costs.
- Focusing on quality and pre-screening (being unafraid to be selective based on attitude, aptitude, etc.)

Community College Best Practices

At the community college level, a growing number of well-established programs have good track records of training students—often post-baccalaureate students—in hands-on skills required by local employers. Many of these programs also are beginning to feature growing articulation with specialized bachelor's degree programs developing in biotechnology.

This analysis features the Austin Community College Biotechnology Program because it is in a peer state facing many of the same issues as Arizona.

The Austin Community College Program offers an Associate of Applied Science Degree as well as a Certificate in Biotechnology. Its focus is to provide the biotechnology experience to prepare students to work as entry-level biotechnicians in a variety of laboratory or biomanufacturing settings. Given the mix of employers, ACC seeks to ensure that students can offer skills to medical labs (particularly as histologists) in testing food, water, and soil and in quality control and assurance. Specific skills developed include lab methods and instrumentation; quality control and assurance; and analytical lab, histological, and immunological techniques.

ACC learned from others who came before it. The program researched the San Diego City College program in detail and seeks to draw on existing skill standards.

ACC customized its curriculum to fit its local employer base, such as incorporating histological techniques to serve medical labs and ribonucleic acid analytical techniques to serve a key employer. Nevertheless, ACC seeks to balance the customization to local employers with a broad curriculum to compete with California, which is a major draw for students.

ACC offers some novel approaches including a "graduate guarantee": if students fail to demonstrate the needed expertise on a standard technique, the school will train them for free. ACC is very outreach oriented and is seeking to actively cultivate local high school students through dual courses, including courses taught by high school teachers trained by ACC.

Looking to the future, ACC is seeking to develop programs to serve working professionals in the biotech industry, including providing continuing education programs in new emerging skills, and offering custom and contract training programs, which can be useful in economic development recruitment efforts.

Four-Year Degree Level

As mentioned earlier, four-year institutions generally are not succeeding in equipping their biology students with the hands-on skills needed to work in laboratory or biomanufacturing settings. With recent cost pressures, the ability to create laboratory space is under real threat across public institutions throughout the nation.

The California State University System's Program for Education and Research in Biotechnology (CSUPERB) stands out, even though it is not a specific undergraduate program, because of the multifaceted approaches it has taken. Generally, students at the A.A. level in California can articulate even the most hands-on courses to bachelor's degree programs offered at CSU campuses.

CSUPERB is a multicampus initiative created in 1987 to focus the resources of the California State University on a system-wide basis on biotechnology. Since its inception, the program has made 180 grant awards for curriculum development, joint ventures with industry, and creation of new facilities. CSUPERB holds an annual symposium for faculty and students focusing on key development in biotechnology and provides funding for faculty and students to travel to national and international conferences and workshops. The program is tightly interfaced with industry. CSUPERB plays a catalytic role with the various CSU campuses, providing funds that can be used to hire new instructors and to create new technical programs.

The current annual budget is $1.4 million, but the program is slated to grow to $12 million by 2009. It is hoped that the budget will increase to $5 million in the next 18 months. In addition to its state appropriation, CSUPERB receives about $5 million in matching funds and $6 million to $7 million in gifts on an annual basis.

Support of CSUPERB has enabled CSU's 22 campuses to expand its offerings of degrees in biosciences to include biotechnology, biochemistry, molecular and cell biology, microbiology, agricultural biotechnology, biotechnology entrepreneurship, regulatory affairs, biotechnology-related engineering, and bioinformatics. In many cases, emphasis in these areas is provided within the biology major.

Special Programs: CSUPERB manages several grant programs designed to support biotechnology research and education. They include

CSU Biotechnology Programmatic Development Grant Program. This program provides grants of up to $15,000 to support the development of curriculum, workshops, and short courses. Greatest consideration is given to projects that are multidisciplinary and multicampus and that promote academic industry linkages.

Faculty-Student Collaborative Research Seed Grant Program. This program makes awards of up to $10,000 to young faculty to enable them to prepare grant applications for external research funding. All projects funded must have substantial involvement of students.

Faculty Travel Grants. CSUPERB makes $500 awards to enable faculty to participate in national and international professional meetings and workshops related to biotechnology.

Biotechnology Student Travel Grants. CSUPERB makes $900 awards to encourage students to present their biotechnology research findings at national and international professional meetings.

Entrepreneurial Joint Venture Matching Grant Program. This program provides $1,000 to $25,000 on a matching basis for promising entrepreneurial joint ventures. Projects must be a collaborative effort of a CSU faculty member and other individuals or institutions and result in positive economic development impacts.

Graduate Degrees and Professional Development

At the graduate level, the trend is toward advancing new multidisciplinary degrees to meet the challenges facing the biosciences as they move from theory into practice and must integrate many converging areas of technology. This phenomenon is critical for training first-class Ph.D.'s able to advance new research discoveries and product development. The rise of bioengineering is a direct reflection of this trend; and programs at Georgia Tech, Rice, Stanford, and many other top-tier institutions reflect this activity. But, this is more a basic research than a workforce focus.

What is particularly important in a workforce development context is the ability to offer a professional degree program that adds real value to existing bioscience professionals. The one program that stands head and shoulders above other professional graduate degree programs in the United States is that offered by The Johns Hopkins University. Unlike most other bioscience workforce development oriented programs, it operates at a scale that makes a difference on the overall bioscience sector in Maryland. This program, which is now more than 10 years old, has proven itself because of its ability to evolve over time. It began as a very science-oriented program, but is now known for its excellence in bioenterprise management. Increasingly, it is a key degree for those seeking regulatory affairs and bioinformatics careers as well.

The Master of Science in Biotechnology Program at The Johns Hopkins University engages more than 500 students in coursework each semester. The typical student, in his or her late 20s or early 30s, is a current bioscience worker with a bachelor's degree. Another significant source of students are attorneys working with the bioscience industry.

The program offers a wide ranging curriculum involving 34 course offerings across core sciences, bioinformatics, regulatory affairs, and bioenterprise management. The program requires 10 courses to complete the master's degree, typically taking two years to complete on a part-time basis, with four core courses involving biochemistry and advanced cell biology. Students have the opportunity to concentrate on particular career tracks including bioinformatics, regulatory affairs, and biotechnology enterprise. This focus on career tracks was added as the program responded to student interest and needs, though many students decide not to concentrate and instead pick and choose electives across these areas.

The program director sees regulatory affairs emerging as a major area where growth in the program is reflecting the maturing industry in Maryland.

The bioenterprise management focus also has been augmented with a new combined M.S./M.B.A. program that can be completed in three years.

A certificate in biotechnology enterprise is available for those desiring a deeper understanding of the business aspects of biotechnology without completing an entire master's degree program—the certificate requires six courses. Students desiring to continue in the program can count four courses toward the 10 required for the master's degree in biotechnology.

Summing Up—Lessons Learned

Based on discussions with interviewees in many of the benchmark states, several interrelated lessons emerged.

Keys to Success

Those interviewed strongly agreed on the following prerequisites for advancing a successful bioscience workforce program:

- **Significant industry involvement.** This is perhaps the most universally held success factor found across programs in the benchmark states. As one program director explained: "Because they work so closely with industry, the students are trained exactly as industry needs them."

- **Hands-on laboratory approach to curriculum taught by those in industry.** This ensures that students understand real-world work requirements and applications. Industry instructors are particularly important in teaching courses more related to regulatory affairs, such as good laboratory and good manufacturing practices.
- **Generally, the unavailability of a hands-on laboratory curriculum is a real weakness of existing bachelor-level biology programs.** It may be hard to overcome given the expense of establishing lab facilities that can serve large numbers of biology students, many of whom will be going on to professional schools or graduate education.
- **More specific laboratory skills development for those with bachelor's degrees in the biosciences.** Those already having earned a four-year degree in the biosciences are an important audience for hands-on bioscience skills development. This has been found to be true across the country and reflects the more theoretical knowledge taught at most undergraduate bioscience degree programs.
- **An established industry base.** This is a key enabling factor for advancing the variety and depth of bioscience programs. It is clear that both California and Maryland have a much greater variety and depth to their bioscience workforce programs.

Barriers to Overcome

Across the many programs discussed in this analysis—even in the leader states of California and Maryland—barriers such as the following were raised that reflect resources applied:

- **Lack of standardization within the biosciences industry on skills for specific types of positions**. Stated differently, much variation in industry needs makes it difficult to address skills in a consistent way similar to those for medical techs or IT positions. This places a burden on programs and may limit their effectiveness more broadly.
- **Insufficient numbers of trained faculty members**. This results in difficulty meeting the stated demand by industry.
- **Weak marketing of programs to industry**. Efforts are particularly needed in building the personal relationships that help develop confidence in the programs being offered that can overcome bias against A.A. degree holders. Many of those interviewed commented that higher education does not have a strong record of knowing how to market itself.
- **Lack of statewide coordination**. A patchwork of programmatic efforts with little scale or strategic focus is emerging across the benchmark states. This makes it difficult to gain the needed resources to support the growth of needed programs. California and Washington are the only states that come close to addressing this need for coordination.
- **Lack of access to laboratory facilities**. This is a problem even for many of the campuses in California.

Strategic Issues

As Arizona considers how best to address bioscience workforce development, a number of key issues are raised from the benchmarking exercise:

1. **How should Arizona most effectively address relationships across high school, community college, four-year degree, and professional graduate programs?** Do Arizona employers fit the mold of seeking four-year degree holders or are they more open to A.A. degree holders? Can Arizona find unique ways to address this national problem? Are the key champions in Arizona among bioscience employers who can set the stage for a broader hiring base across degree levels than found in Maryland or Georgia? How can A.A. degrees in Arizona best be articulated in a program manner to four-year degree programs?
2. **How should skills be customized for Arizona, particularly in light of the major presence of clinical care?** Even more than the Austin area, which, unlike other biotechnology programs, offers at least a limited thread of histological and immunological techniques sought by medical labs, Arizona has a significant and growing hospital subsector. How can this best be factored into program offerings?
3. **How should Arizona assess what is needed for the biomedical device subsector?** One area that has been lacking in the benchmark states is that of biomedical devices. Discussions with Bio-Link revealed that this is not only a reflection of the industry mix found across the benchmark states, but also a reflection of the state of postsecondary career education. The closest most states come is to have a bioengineering program. Only one identified A.A. degree biomedical device program exists in the nation—in Minnesota (Note: Battelle is following up on this program). However, the lack of such workforce development programs may reflect that the skill needs for biomedical devices are more akin to the manufacturing sector involving machining skills. The question is whether the past is a good indication of the future.
4. **How should Arizona position bioscience workforce development as an economic development tool?** Arizona needs to think strategically and proactively about how it can best create a bioscience workforce development capacity to support its economic development objectives, especially given its close proximity to California. For instance, in light of the cost advantages and reduced risks of earthquakes, should Arizona consider aggressive marketing for biomanufacturing activities, which today is not a skill much in demand in Arizona? How would the need for a biomanufacturing-trained workforce be addressed? Alternatively, given the strong optics and semiconductor strengths in Arizona, could medical devices or biodefense products play a strong role in economic development, and what role should workforce development play in that activity?

Strategic Bioscience Workforce Development Initiatives for Arizona

Next Generation Approach

This is an opportune time for Arizona to complement its ongoing investments and activities in supporting the development of the state's bioscience cluster with a set of focused and strategic workforce development initiatives. In particular, Arizona has an opportunity to put in place a "next generation" workforce development approach that aligns in a more fundamental and sustainable manner the demand for bioscience workers across the full spectrum of educational and training providers.

As the National Governors' Association report on State Leadership in the Global Economy explains:

> "The next generation of workforce development policies must engage the private sector and the entire public-private enterprise of training and education, starting in elementary and secondary school and continuing through college and working life. In this vision, workforce policies no longer address the "second chance" systems as they have in the past, but they are customized to the needs of individuals and employers and are linked closely to the economic priorities of states and communities."[6]

Traditionally, workforce development approaches—especially in scientific and technology areas—have been driven by educational requirements rather than a focus on the skills needed for the workplace. This is clearly the case in the biosciences where higher educational institutions have largely defined the range of programs and the specific content of knowledge and experiences that guide student preparation.

The need for such a next generation approach for bioscience workforce development in Arizona clearly emerges from this detailed study of demand and supply factors for bioscience workforce development. ***While Arizona is expected to experience robust employment growth in bioscience employment across key technical occupations spanning research, laboratory sciences, production and management support, there is a clear mismatch in the specific areas of demand and key trends in supply.***

Examples of specific areas of mismatch include

- **Laboratory sciences.** A significant and growing bioscience occupational area for Arizona is found in laboratory sciences, spanning both healthcare and research environments. Yet, few educational programs today address this need, and existing programs (especially in the healthcare laboratory) suffer from low enrollments.
- **Large generation of biology students lacking employable laboratory skills.** Arizona stands out in the growth of its biology degrees, particularly at the undergraduate level, growing by 15 percent compared with just 1 percent nationally. The number of biology-

[6] National Governors' Association, "A Governor's Guide to Creating a 21st-Century Workforce," State Leadership in the Global Economy Task Force, page 12, 2002.

related majors now stands at nearly 900 annually in Arizona. However, these biology students are generally not fully prepared to undertake the hands-on laboratory work required in healthcare and research settings. And the trend is toward fewer laboratory instructional experiences for students in Arizona.

- **Lack of educational and training curriculum in regulatory affairs and quality assurance for medical devices.** Beyond the facts that medical devices are Arizona's largest nonclinical bioscience industry and production workers are the largest occupational grouping employed by bioscience employers, there is no active effort to provide training for workers entering that highly regulated environment requiring specific quality standards.
- **Graduate degree programs in the biosciences are falling just as the demand for postdoctoral scientists in Arizona is soaring**. Arizona has recorded a sharp decline in Ph.D. and master's graduates in the biosciences in recent years. Yet, a strong demand for research scientists is expected in Arizona in the next several years, with most of the positions to be filled by recent advanced degree graduates.

Underpinning these demand and supply mismatches in Arizona are deeper issues that must be addressed, including

- The disconnect between bioscience employers and educational institutions in sharing information, setting priorities, developing needed programs, and addressing the curriculum
- Lack of capacity in the biosciences across the educational system, especially for specialized programs and advanced degrees
- Limited awareness by Arizona residents—particularly school-age youth and those seeking new careers—of the opportunities to pursue bioscience careers, and a need for proactive steps to increase access to these career opportunities, especially among minority populations.

At the same time, as the economic priorities of Arizona are placing a clear emphasis on the bioscience cluster, opportunities exist for Arizona to make workforce development a key driver and contributor to an overall bioscience economic development strategy for the state. Workforce development can provide both a resource for emerging and start-up bioscience ventures in Arizona as well as an advantage to attract investments and operations from existing bioscience companies, particularly from the West Coast.

Specific strategies and actions are needed for Arizona to address the demand and supply gaps in a systematic and sustainable manner that pinpoints the underlying challenges as well as seizes the economic development opportunities.

Vision and Mission

The vision for the Arizona in bioscience workforce development can be summarized as follows:

Arizona will succeed in its bioscience workforce development efforts by establishing a demand-driven bioscience workforce approach that broadly emphasizes access to bioscience careers for Arizona residents.

The state's mission is that, a decade from now, the outside world will acknowledge the following:

Arizona educational and training institutions are recognized as having a highly collaborative partnership with bioscience employers that spans broadly across educational institutions at all levels, serving to

- Enable Arizona to identify specific occupational and skill needs based on timely information gathering and specific mechanisms that translate employer needs into on-the-ground programs and curricula
- Reach out to students, parents, and those workers seeking to change careers or advance in the biosciences.

The responsiveness and agility of Arizona's advanced bioscience workforce system serve as a competitive advantage for the state not only in helping to grow home-grown Arizona bioscience companies, but in attracting investments from companies outside of Arizona.

STRATEGIES AND ACTIONS

Table 12 lists the five specific strategies and 26 associated actions proposed to accomplish this vision and achieve this mission. The five strategies are as follows:

- **Advance bioscience career pathways** ***to integrate industry needs for bioscience workforce development in a seamless fashion across broad spectrum of educational institutions.***
- **Promote access** ***to bioscience careers and ensure that bioscience career initiatives serve Arizona's diverse population.***
- **Build capacity** ***across educational institutions for bioscience workforce development that can be broadly shared and leveraged.***
- **Conduct ongoing strategic assessment** ***in a manner that institutionalizes the continued evaluation of bioscience workforce demand and alignment with supply to guide program and curriculum development and advance outreach efforts.***
- **Establish an economic development focus** ***that positions bioscience workforce development as a proactive tool for economic growth for the state.***

Critical and immediate actions are discussed further at the end of this section.

Table 12: Summary of Proposed Strategies and Actions with Priorities and Time Frames

Strategy	Actions	Priority	Time Frame
Strategy One: Advance bioscience career pathways	Establish a statewide bioscience industry-education council to foster strong partnerships, involving ongoing industry guidance on program offerings and career pathways.	Critical	Immediate
	Prioritize the development of bioscience programs based on a systematic process that aligns the demand and core skill sets in existing and emerging career pathways with ongoing educational program offerings and curricula.	Critical	Near term
	Design 2+2+2 career preparation programs rather than stand-alone degree efforts.	Critical	Near term
	Ramp up laboratory sciences across the state in a defined career pathway approach.	Significant	Long term
	Address education and training development needs for careers in biomedical production and related management support occupations.	Significant	Long term
Strategy Two: Promote access to bioscience careers and ensure that bioscience career initiatives serve Arizona's diverse population	Undertake a broad public marketing effort on bioscience careers that raises the public's understanding of bioscience career opportunities and specifically targets students, parents, and guidance counselors.	Significant	Near term
	Offer specific bioscience career awareness activities in K-12 involving enriched educational experiences with experiential learning opportunities.	Critical	Immediate
	Develop specialized approaches, such as broad-based mentorship and extracurricular efforts, to reach out to at-risk minority and economically disadvantaged students from the early grades.	Significant	Near term
	Ensure that personalized services for minority, economically disadvantaged, and at-risk students found in K-12 and community colleges are continued as students progress at the four-year and graduate levels.	Significant	Immediate
	Work with industry to create customized retraining programs for current nonbioscience workers who demonstrate an aptitude to enter bioscience careers.	Critical	Near term
	Focus on bioscience skill upgrading for those trained in the biosciences or in existing bioscience positions, including postbaccalaureate programs.	Significant	Near-term

Table 12: Summary of Proposed Strategies and Actions with Priorities and Time Frames (continued)

Strategy	Actions	Priority	Time Frame
Strategy Three: Build capacity across educational institutions for bioscience workforce development that can be broadly shared and leveraged	Develop a shared, common vocabulary on bioscience workforce terminology.	Critical	Start immediately or as soon as possible, but will be long term
	For identified fields of biosciences, focus on developing industry-driven skill standards translated into core curricula to ensure comprehensive, high-quality, and responsive program efforts.	Critical	Immediate
	Pursue shared-use approaches for deploying program resources statewide.	Critical	Near-term
	Dedicate funding for recruitment of topflight bioscience graduate students to Arizona.	Important	Long term
	Develop a clearinghouse capability to broaden communications across students, employers, educational institutions, and parents on bioscience careers, educational opportunities and requirements.	Important	Long term
	Strengthen K-12 math and science programs (Project Lead The Way, enrichment activities, etc.).	Critical	Long term
Strategy Four: Conduct ongoing strategic assessment in a manner that institutionalizes the continued evaluation of bioscience workforce demand and alignment with supply to guide program and curriculum development and advance outreach efforts	Develop ongoing occupational and skill needs assessment of employers, using regular vacancy surveys, occupational profiling, and other techniques.	Significant	Immediate
	On a periodic basis, complete surveys of bioscience workers to learn their educational and training needs.	Important	Long term
	Develop a specialized labor market research capability under the guidance of the bioscience industry-education council.	Significant	Near term
	Using the forum of the bioscience industry-education council, convene regular industry-education dialogues to discuss trends and issues arising across bioscience fields.	Critical	Immediate

Table 12: Summary of Proposed Strategies and Actions with Priorities and Time Frames (continued)

Strategy	Actions	Priority	Time Frame
Strategy Five: Establish an economic development focus that positions bioscience workforce development as a proactive tool for economic growth for the state.	Develop and market bioscience workforce capacities targeted to specific bioscience industry segments within niche areas of bioscience activity where Arizona has broad-based competitive advantages.	Critical	Immediate
	Provide matching funds for the development of specific company-based curriculum and program needs to be served through postsecondary institutions based on guarantees of job hires.	Significant	Near term
	Establish programs targeted to postdocs serving at Arizona academic institutions as prospective industry scientists and entrepreneurs.	Important	Long term
	Develop a pilot biomanufacturing program in Arizona as a lead investment for targeting recruitment of biomanufacturing facilities to the state.	Important	Long term
	Provide relocation assistance and other services to help in the recruitment of senior business executives and scientists by emerging and start-up bioscience firms.	Important	Near term

Strategy One: Advance bioscience career pathways to integrate industry needs for bioscience workforce development in a seamless fashion across broad spectrum of educational institutions.

Background:

Bioscience workforce development in Arizona—as is true in much of the United States—is driven by educational requirements rather than a focus on the skills and career opportunities found in the workplace. As the National Governors' Association has found: "the traditional approaches to workforce development are rooted in the supply side of the labor market, building the skills of job entrants with minimal input from employers or regard for how these skills are further developed and used in the workplace."[7]

Arizona needs to break this cycle by focusing on bioscience career pathways across the educational spectrum. Career pathways focus on moving students seamlessly from one level of education to the next in their chosen field of study, with specific "exit" points to allow them to pursue job opportunities, while still advancing their careers with further education and training. These career pathways need to be developed in close connection with industry around specific skill standards that are then integrated across the curriculum. Given the advanced technical

[7] National Governors' Association, "A Governor's Guide to Creating a 21st-Century Workforce," State Leadership in the Global Economy Task Force, page 12, 2002.

nature of bioscience skills, with many bioscience careers requiring bachelor level and more advanced degrees, program articulation is critical.

While interest and activities in bioscience program development are growing across educational institutions in Arizona, these efforts are generally not being developed with career pathways in mind. There is a clear disconnect between "career" and "academic" programs that needs to be bridged so that students can develop employable skills while advancing their education and pursuing their career development in the biosciences in a clear tracked approach.

Tackling career pathways is not an easy matter in the biosciences. Emerging fields in the biosciences—from research lab skills to medical device development—lack standardization nationally; therefore, many employers substitute a requirement for a bachelor's degree as a proxy for specific skill standards. In the more developed healthcare lab science fields, credentialed programs have been developed; but, they do not fit together easily in a sequence.

Best Practices:

One key for success in advancing career pathways is to ensure program articulation, where community college degrees can seamlessly link with higher level degree programs. Even among leading bioscience states, such as Maryland and California, an uneven pattern of articulation exists at the postsecondary level. Many of the specific hands-on courses offered at community colleges simply do not articulate into established bioscience programs found at the four-year level—reflecting the differences between traditional bioscience degrees and bioscience career programs. For instance, the core bioscience workforce programs found at Montgomery College in Maryland do not articulate with University of Maryland flagship campuses, while the City College of San Francisco articulates only with the California State University (CSU), not the University of California.

Successful program articulation in bioscience career education reaching to the bachelor's degree level appears to call for new types of bioscience bachelor's degree programs at the four-year level that can recognize the value of the hands-on bioscience skills curriculum offered at the community college level. For example, a new bachelor of science degree in molecular biology, biochemistry, and bioinformatics ("MB3" program) at Towson State in Maryland successfully articulates with community college programs in Maryland, while traditional biology degree programs at the University of Maryland do not.

Another key to advancing career pathways is to gain local employer involvement up front in program and curriculum development. Particularly in light of the lack of standardization, local employers are key to designing successful programs that allow workers to be employed. Employer involvement has been key to advancing nontraditional programs that seek to find employment opportunities for students below the bachelor's degree level in more laboratory science fields. The BioTechnical Institute of Maryland (BTI) and the Berkeley Biotechnology Education, Inc. (BBEI) have successfully overcome this resistance. To do so, however, these small-scale initiatives required champions from the bioscience employer community willing to think "outside the box."

Actions for Strategy One: Advancing Bioscience Career Pathways

The actions for advancing career pathways involve some key foundational steps along with specific opportunities identified from the strategy development process.

The following three **foundational action steps** are proposed:

- **Establish a statewide bioscience industry-education council to foster strong partnerships, involving ongoing industry guidance on program offerings and career pathways.**
- **Prioritize the development of bioscience programs based on a systematic process that aligns the demand and core skill sets in existing and emerging career pathways with ongoing educational program offerings and curricula.**
- **Design 2+2+2 career preparation programs rather than stand-alone degree efforts.**

These two additional specific career pathway opportunities are proposed:

- **Ramp up laboratory sciences across the state in a defined career pathway approach.**
- **Address education and training development needs for careers in biomedical production and related management support occupations.**

Action 1: Establish a statewide bioscience industry-educational council to foster strong partnerships, involving ongoing industry guidance on program offerings and career pathways.

As mentioned previously, gaining local employer involvement up front in program and curriculum development is key to advancing career pathways. The biosciences offer particular challenges in establishing skill standards because, nationally, there is a lack of standardization on skills for specific types of positions. Instead, successful programs in bioscience workforce development must be highly customized to local employer needs and maintain a strong connection to employers as students are placed in jobs.

The role of the statewide bioscience industry-education council would include

- Informing the development of skill standards, leading to curriculum development for Arizona in the biosciences
- Identifying specific program offerings at different levels of education and how they can be best connected
- Helping to pilot new program and curriculum approaches
- Developing a roster of industry scientists and engineers who can mentor students and serve as co-teachers or adjuncts, particularly for more regulatory and quality assurance courses
- Enabling key capstone projects and internships that raise the employability of students
- Placing graduating students with employers.

To be effective, the bioscience industry-education council will require resources that it can direct, particularly for new program and curriculum development. Access to resources would enable the council to provide co-funding and other incentives for collaboration of educational institutions in establishing on-the-ground programs and new curricula.

This council does not need to be a new organization, but can be organized as part of an existing technology or bioscience trade association in Arizona.

Action 2: Prioritize the development of bioscience programs based on a systematic process that aligns the demand and core skill sets in existing and emerging career pathways with ongoing educational program offerings and curricula.

Arizona needs a rigorous and comprehensive effort that systematically identifies key occupational groupings in demand and then brings together employers and educators to identify the core skill sets required, how these skill sets fall into a career model in which workers can advance, and how these skill sets can be integrated into educational programs and curricula. The statewide bioscience industry-education council can provide a forum for this effort, but more focused activities need to be emphasized. Washington State successfully carried out a similar effort. The state's Workforce Development Fund financed an effort involving community colleges, labor, businesses, universities, and K-12 schools to first develop and validate industrial skill sets within high-priority occupational fields and then focus on an articulation and gap analysis of existing and future biotechnology educational programs at K-12 schools, community colleges, and universities as they relate to these skill sets.

Based on the findings of the demand analysis in this report, two specific occupational fields seem ripe for this type of systematic alignment effort in Arizona, namely laboratory science and medical device occupations.

Action 3: Design 2+2+2 career preparation programs rather than stand-alone degree efforts.

The analysis of educational activities in the biosciences revealed that Arizona is generally very active in promoting articulation between community colleges and the public universities, as well as a growing number of private universities; but, significant gaps in articulation exist at the program level for bioscience programs.

For emerging bioscience fields, many of the A.A. degrees in the biosciences—such as Mesa Community College's biotechnology degree or Yavapai's agricultural technology degree—have become terminal degrees rather than seamlessly articulating to academic four-year degree programs, despite the importance of bachelor's degrees to career development. Meanwhile, the few new specialized bachelor's degree programs, such as ASU's Molecular Biosciences and Biotechnology and DeVry's biomedical engineering technology, do not have strong program articulation with lower level degrees.

For healthcare lab technician positions, an area where Arizona needs to ramp up, there are no well-defined and marketed programs enabling students to go from community college programs, of which few exist today, to four-year degree programs, which are small and under threat of being closed.

To break out of the typical mindset, Arizona needs a new approach to program development. Programs need to be developed in concert, showing how they would link with lower and higher degree programs and how they address specific employer skill mixes identified through the bioscience industry-education council.

Arizona may need to consider new types of bioscience programs at the two-year and four-year degree levels that can be better connected with skill sets being acquired at each level that enable employability by students.

For the biosciences, there may be opportunities for linkages going back and forth across the educational levels rather than simply progressing linearly from community college to four-year degree programs. For instance, a student receiving a traditional biology bachelor's degree, who decides against graduate school or any medical-related professions, might find some key employability skill in "laboratory science skill" classes offered at the community college level.

Action 4: Ramp up laboratory sciences across the state in a defined career pathway approach.

The analysis of demand and supply factors resulted in one clear and major finding: Arizona needs to ramp up laboratory sciences. The bioscience employer survey found that demand for laboratory technicians and technologists is expected to grow by 32 percent over existing employment levels in the next two years, with 535 new hires expected. Already, laboratory technicians and technologists are among the largest occupational areas in the biosciences. At the same time, this field has little capacity across educational institutions and is not drawing students to existing programs.

Traditionally, the fields of healthcare laboratory and research laboratory technicians have been treated as separate domains, both in education and in industry. Yet, from discussions with research laboratory and healthcare laboratory managers, the Battelle team learned that there are clear sets of skill overlaps and opportunities for converging curricula and facilitating career pathways for students of laboratory sciences.

The core similarities between healthcare laboratory and research laboratory professionals involve the need for GLP. Table 13 shows these similarities in training. Where the two fields tend to diverge is in the specific laboratory techniques used and the educational backgrounds needed to be successful. However, in the future, as molecular biology becomes more and more a part of health care diagnosis and treatment, major convergence between research lab professionals and healthcare laboratory professionals is expected to take place. New applications such as genotyping to identify health risks for diseases and more advanced tissue analysis are expected to become part and parcel of modern healthcare laboratory efforts.

This strategic assessment is proposing that Arizona break down the traditional boundaries between research and healthcare laboratory sciences. The bullets below illustrate the potential for organizing these laboratory science activities across the educational spectrum with connections to job positions:

- Secondary Level: More preparatory in nature, with emphasis on routine laboratory activities, such as clean room practices, specimen handling, lab computer tracking systems, and cleaning and sterilization. Positions would be low-level technical support, well below any technical specifications.
- Associate's Degree Level: Lower level biology, microbiology, molecular biology, and chemistry courses. Strong laboratory skills development involving GLP, documentation, instrumentation, equipment maintenance, and basic techniques in cell and tissue culture. Specific career tracks might include histology, clinical lab technician, and research lab technician.

Table 13: Blending of Skill Sets Across Bioscience Research Laboratory and Clinical Laboratory Science

Skills	Bioscience Research	Clinical
Perform Tests/Assays	X	X
Obtain Specimens or Materials	X	X
Process Materials	X	X
Control Inventory	X	X
Maintain Equipment and Facility	X	X
Evaluate, Document, and Report Results	X	X
Communicate and Document Information	X	X
Maintain Professional Competency	X	X
Train Others	X	X
Maintain Quality Assurance	Emerging	X
Manufacture Products	X	Limited
Meet Regulatory Practices	Emerging	X
Perform Initial Research	X	Limited

Source: Adapted from initial work by Linda Ross, University of Tennessee Medical Center.

- Bachelor's Degree Level: More specific tracked academic courses feeding into (a) medical technology program to obtain licensing as a medical lab technologist; and (b) molecular biology and biotechnology degree program that might have tracks to qualify students for specialized categorical healthcare lab positions (in concert with the medical technology program), such as in immunology, molecular medicine, and microbiology or research-level positions dealing with specialized techniques such as genomic sequencing and analysis, genotyping, protein analysis, and scaling up.
- Postbaccalaureate Certificates: Targeted to traditional biology students seeking to gain hands-on employability skills for laboratory science positions offered through community colleges. A highly condensed program taken after graduation or during senior year.

Action 5: Address education and training development needs for careers in biomedical production and related management support occupations.

Linking across the medical device industry may be another way to develop bioscience career pathways in Arizona, starting with production-oriented occupations through management support occupations.

The technical skill sets required by medical device manufacturers in Arizona are diverse and more akin to those of other types of manufacturing (e.g., machining, CAD, electronics, mechanical and electrical engineering, and material sciences) rather than related to the biosciences.

But, a key theme linking medical device manufacturers is the quality and regulatory standards they face for their products, which can represent a critical skill set that covers production to management support occupations.

A first step recommended for Arizona is to advance specialized courses and short-term programs that can be helpful in training workers on these quality and regulatory requirements. These specialized quality and regulatory skills can help dislocated workers seeking to enter the biomedical product field, while also upgrading the skills of line production workers. It is surprising that, nationally, there are few postsecondary programs to train workers for biomedical product careers. Anoka-Ramsey Community College in Minnesota has one of the only existing programs, initiated about two years ago to support Medtronic and its suppliers in the region. It focuses on regulatory requirements, quality standards, and production aspects for medical devices. Over the past two years, more than 42 students have been placed into biomedical technician positions.

In the future, Arizona also must engage the medical device industry in more interactions on skill needs as biological concepts that increasingly will be integrated into medical device production. Today, however, this is not a major area of concern.

Ideally, a seamless career pathway approach from production line to management support would seem to make sense. However, a key challenge is the chasm between shop floor work, typically calling for a high school degree and some vocational training, and higher level quality control, regulatory affairs, and process engineering, typically requiring a bachelor's degree. Further discussions are needed with industry to identify how community colleges can bridge this chasm—perhaps providing the initial foundations for higher degrees while infusing production line workers with hands-on regulatory and quality assurance skills that enable them to serve in oversight or analytical positions on the shop floor.

Strategy Two: Promote access to bioscience careers and ensure that bioscience career initiatives serve Arizona's diverse population.

Background:

A broad outreach to Arizona residents is important in making them aware of the significant career opportunities in the biosciences, especially in areas with strong employment growth but lagging enrollments—such as laboratory sciences and graduate education. This outreach is an opportunity to broaden the public's understanding of the positive effects the biosciences can have on the state's quality of life and economic health.

Still a key mark of success in Arizona bioscience workforce development is the ability to create a diverse workforce, opening access to minority students, those existing workers seeking to change careers, and those existing workers seeking to advance their careers in the biosciences. Arizona's bioscience workforce is already diverse, particularly in production-oriented occupations. A large Hispanic population is working in line production positions and facing difficult issues in skill upgrading because of language barriers.

Diversity through career changing also is evident in the biosciences in Arizona: with the downturn in the semiconductor and electronics industry, laid-off electronics workers are turning to medical device manufacturers in Arizona who specialize in integrating electronics. Again, these career changers face challenges in learning the regulatory and quality requirements for biomedical production.

Perhaps the greatest challenge in promoting access to bioscience careers is reaching young minority students, who are very underrepresented in science and math courses, and giving them the orientation and tools to pursue these careers.

Best Practices:

The benchmarking analysis identified that, across biotechnology and medical technology programs, typical students were those who are already pursuing or have received bioscience-related degrees.

A limited number of workforce development programs in the biosciences are succeeding in opening career opportunities to nontraditional bioscience workers, particularly minority youth. The two following programs stand out as best practice examples of linking high school students into bioscience careers:

- **Berkeley Biotechnology Education Inc**.—A fully integrated program that involves targeted high school courses in the eleventh and twelfth grades, a paid internship between the two grades, a paid internship between high school and community college, four community college courses, and a paid year-long co-op work experience in industry while in college. The curriculum is developed by joint industry-high school/community college work groups. The program has been highly successful in meeting its objectives. Approximately 95 percent of BBEI students are youths of color, and 60 percent are female. All graduates of the certificate program have been offered regular jobs after program completion, and 50 percent of these are continuing their education in A.S. or B.S. programs while employed. Many of the students are the first to graduate high school in their families, and most are the first to attend a postsecondary education institution.
- **BioTechnical Institute of Maryland**—A free-standing organization outside of the high school system, which works primarily with minority high school graduates who have been working in dead-end jobs. The program has identified, in close collaboration with industry and research organizations, a specific set of skills for students to qualify for entry-level positions as lab assistants. It is a highly focused 12-week program, with the first nine weeks focused on in-class training and the last three weeks on on-site internships with participating organizations. The curriculum is very specific, involving clean room practices and techniques in cell culture, laboratory safety and GLP, cleaning and sterilization, gowning, weights and measurements, laboratory math, introductory animal care, and molecular biology. Since its formation in 1998, 105 graduates have been placed. Currently, approximately 50 to 60 students are trained per year in its laboratory technician program, with an expected placement rate of 80 percent.

Another innovative program is the STEP program in Baltimore, Maryland, which targets existing nontechnical workers in hospitals—such as janitors, housekeepers, and security guards—to advance them into entry-level clinical care positions. The hospitals are actively involved in identifying prospective students among their workforce and in providing for paid release time to upgrade their skills. Funds from the State of Maryland are used to develop and operate the program. While the STEP program does not address laboratory science fields, it suggests an approach to opening up bioscience careers more broadly.

Actions for Strategy Two: Promoting Access to Bioscience Careers

Six specific action steps are recommended for advancing access to bioscience careers:

- **Undertake a broad public marketing effort on bioscience careers that raises the public's understanding of bioscience career opportunities and specifically targets students, parents, and guidance counselors.**
- **Offer specific bioscience career awareness activities in K-12 involving enriched educational experiences with experiential learning opportunities.**
- **Develop specialized approaches, such as broad-based mentorship and extracurricular efforts, to reach out to at-risk minority and economically disadvantaged students from the early grades.**
- **Ensure that personalized services for minority, economically disadvantaged, and at-risk students found in K-12 and community colleges are continued as students progress at the four-year and graduate levels.**
- **Work with industry to create customized retraining programs for current nonbioscience workers who demonstrate an aptitude to enter bioscience careers.**
- **Focus on bioscience skill upgrading for those trained in the biosciences or in existing bioscience positions, including postbaccalaureate programs.**

Action 1: Undertake a broad public marketing effort on bioscience careers that raises the public's understanding of bioscience career opportunities and specifically targets students, parents, and guidance counselors.

Many of the leading and peer benchmark states engaged in bioscience workforce development have tended to be passive in their outreach and marketing. This approach of "build it and they will come" is flawed. It fails to reach students early enough to guide their educational decisions, and it fails to provide critical information about the quality of bioscience job opportunities to effectively engage existing workers.

A sustained and active marketing effort is needed to effectively raise the general public's understanding of career opportunities in the biosciences. It makes sense to couple this marketing of bioscience careers with broader marketing efforts to raise the public's understanding of the biosciences. Key activities can include public television programs, a speakers' bureau, a bioscience week involving coordinated public events, and a well-populated Web site with information on bioscience careers and profiles of bioscience workers and employers.

Action 2: Offer specific bioscience career awareness activities in K-12 involving enriched educational experiences with experiential learning opportunities.

Particularly in the middle and high school grades, it is important to expose students to the opportunities for careers in the biosciences. But, it is not only students who are important, but those who help influence their decisions, including parents and guidance counselors.

One exciting effort already underway is the **Arizona Bioengineering Collaboration** (ABC), which began in the fall of 2001 as a four-year project sponsored by a grant from the Howard Hughes Medical Institute to the Arizona Science Center. It brings together educators, researchers, and industry scientists and experts to develop and implement a multicomponent educational program to raise the public's awareness of and interest in local developments in bioengineering and technology. To date, 114 teachers have participated in the teacher training workshops, and an estimated 2,000 students have participated in the student curriculum. The first outreach program was introduced in the spring of 2003, and 100 students have since participated. Thousands of visitors to the Science Center have viewed its DNA demonstration, which has been presented at least three times each week since its introduction in the fall of 2002.

The following are suggested as possible structured opportunities:

- Ensuring that the full range of bioscience career opportunities is presented to students as part of career awareness in the early grades. This presentation can include visiting hospitals, industries or university research labs; inviting bioscience workers, particularly younger workers, to speak to classes; and developing short videos to illustrate a day in the life of a bioscience worker.
- Developing a training program for K-12 guidance counselors to educate them on bioscience careers, including career options, occupational demand information, and educational requirements.
- Developing bioscience-related extracurricular projects targeted for middle school students.
- Arranging events for parents and their children on bioscience happenings in Arizona today.

This effort might be developed as part of the bioscience industry-education council's activities.

Action 3: Develop specialized approaches, such as a broad-based mentorship and extracurricular efforts, to reach out to at-risk minority and economically disadvantaged students from the early grades.

Without a targeted, specialized effort, reaching at-risk minority and economically disadvantaged students and interesting them in bioscience careers will be difficult.

Two specific outreach approaches would be to develop mentoring and extracurricular enrichment programs oriented toward the biosciences and targeted to at-risk minority and economically disadvantaged students across the K-12 system. While mentoring and extracurricular efforts can be distinct activities, it is suggested that they be developed in a more integrated fashion.

Mentoring is a proven method for raising academic achievement, improving student performance, and addressing motivation and self-esteem issues. It is proposed that mentoring be built up to include more career orientation as students advance into middle and high schools.

The recruitment, screening, training, programming, and monitoring of mentors is a major program activity and is best done by a dedicated organization. This effort needs to involve community organizations, churches, and schools in helping to identify students, with a strong outreach to parents.

In the elementary school grades, bioscience workers can mentor minority children by helping them with their basic academic subjects, focusing on reading, math, and writing. This mentoring would be done either during school hours or as part of an after-school program.

In the middle school grades, it is suggested that the mentoring shift toward extracurricular programs in which students participate in science-related fairs and other efforts.

The mentoring in high school can be integrated into biology-related coursework and take on a group approach, focusing more specifically on career opportunities, involving study groups, job shadowing, and special research projects.

Other extracurricular activities might include enriched summer camps focused on the biosciences and science fair activities.

Action 4: Ensure that personalized services for minority, economically disadvantaged, and at-risk students found in K-12 and community colleges are continued as students progress at the four-year and graduate levels.

Growing efforts in Arizona target at-risk minority and economically disadvantaged students to ensure that they are guided and assisted in their educational pursuits in the early grades. These efforts are focused on creating a nurturing and supportive environment for these students. There is a concern that these intensive efforts in the early grades need to be continued as these students progress and face significant challenges, such as more demanding coursework and adapting to mainstream environments. Specific initiatives like mentoring, support groups, after-school enrichment programs, and proactive guidance counseling need to be considered.

Action 5: Work with industry to create customized retraining programs for current non-bioscience workers who demonstrate an aptitude to enter bioscience careers.

Significant potential exists for reaching out to existing workers to make them aware of bioscience career opportunities and equip them to enter specific fields with short-term intensive training programs.

Technology workers in declining fields are finding their way into bioscience fields, especially in biomedical products where technical skills are highly transferable. This effort can be supported by orientation seminars on applying specific technical skills to the biosciences, as well as more structured courses in biomedical regulatory and quality requirements for technical workers seeking bioscience careers.

Less technically trained workers also should be a target for retraining. For motivated workers who are high school graduates and have aptitudes for laboratory sciences, condensed, intensive programs can be successful in training them for basic laboratory support positions. It is critical to involve hospitals and research organizations in this effort and to provide the resources for curriculum development, facilities, and instructors. In particular, borrowing from the experiences of Baltimore efforts with both the BioTechnical Institute of Maryland and the STEP program, it is readily conceivable for Arizona to develop its own targeted entry-level laboratory support program.

Action 6: Focus on bioscience skill upgrading for those trained in the biosciences or in existing bioscience positions, including postbaccalaureate programs.

Access to bioscience careers does not end when workers enter bioscience positions. If Arizona is to retain and advance its bioscience workforce, it must continually reach out to existing bioscience workers with continued life-long learning opportunities. In particular, given the fast pace of innovations in the biosciences, existing bioscience workers may possess obsolete or low-demand skills and need training in emerging skill shortage areas to see a future in the bio-sciences. Another key target for skill upgrading are those workers recruited to entry-level bioscience positions who will need further education and training to have productive careers.

Moving toward robust, life-long learning programs in the biosciences is very much in the state's interest, but difficult for educational institutions to undertake without a sizable market. Yet, without these programs, Arizona's ability to retain bioscience workers is undercut. Initial underwriting of continuing education geared toward existing workers—involving evening and weekend programs that are highly condensed—may be necessary.

Strategy Three: Build capacity across educational institutions for bioscience workforce development that can be broadly shared and leveraged.

Background:

The analysis of Arizona's educational inventory for bioscience workforce development reveals major concerns about the existing capacity of Arizona to meet the workforce demands of bioscience employers in the state. To recap:

- There is a paucity of laboratory science programs in the state.
- There is a lack of sufficient instructional facilities for providing hands-on skills for students in traditional bioscience programs.
- The level of bioscience master's and doctoral graduates is in decline, aggravated by cutbacks in higher education investments.
- There is strong concern about the quality of high school programs in the biosciences, including the quality of teachers.

Addressing these issues requires investment of dollars in facilities, professional development, curricula, and instructors. But, building capacity is not only about levels of investment, but about putting resources to work to raise the capacity of individual schools to participate. Thus, investing funds smartly will ensure that Arizona gets "the most bang for its buck."

Best Practices:

Most states have pursued building capacity one school, one program at a time—both a very expensive and highly inefficient way to approach bioscience workforce development. Typically, something gets sacrificed when specialized bioscience programs have to go it alone, whether it be upgrading of equipment, development of curriculum, quality of facilities, number of instructors, etc.

California is unique in that it is building capacity across educational institutions. Key to California's efforts has been system-wide investments in the biosciences at both the community college and university levels that are coordinated centrally and implemented locally.

For instance, the California State University Program for Education and Research in Biotechnology (CSUPERB) and the California Community College Applied Biological Technologies Initiative (Biotech Initiative) each provide for centralized resources for

- Professional training.
- Curriculum development and curriculum sharing, including availability of grants to individual schools.
- Lab facilities and equipment, including core labs as well as mobile labs. Much equipment comes from industry donations that are coordinated and distributed through the system.
- Outreach to employers for placement and ongoing skills assessment.

Washington State also offers a unique approach toward building capacity focused on building shared consensus on skill needs and applying those skill standards to evaluate program needs and promote articulation. A task force of community colleges, labor, businesses, universities, and K-12 schools, through funding from the state of Washington's Workforce Development Fund, created the skill standards guideline[8] for the state. Not only has the project helped to validate existing programs and encourage new ones to begin, it has also helped to solidify working relationships between and across educational institutions and industry. Though programs are developed by each institution on its own, the project has helped to ensure that programs are cohesive and relate to one another.

Actions for Strategy Three: Building Capacity in Bioscience Workforce Development

Six specific action steps are recommended for building capacity for bioscience workforce development:

- **Develop a shared, common vocabulary on bioscience workforce terminology.**
- **For identified fields of biosciences, focus on developing industry-driven skill standards translated into core curricula to ensure comprehensive, high-quality. and responsive program efforts.**
- **Pursue shared-use approaches for deploying program resources statewide.**
- **Dedicate funding for recruitment of topflight bioscience graduate students to Arizona.**
- **Develop a clearinghouse capability to broaden communications across students, employers, educational institutions, and parents on bioscience careers, educational opportunities, and requirements.**
- **Strengthen K-12 math and science programs (Project Lead The Way, enrichment activities, etc.).**

[8] http://www.wa-skills.com/.

These capacity-building measures are not simply requests for new funding, but embody ways to use funding to raise the capacity of individual schools and create a statewide bioscience workforce system.

Action 1: Develop a shared, common vocabulary on bioscience workforce terminology.

A key capability needed in Arizona to bring together the broad base of organizations involved in bioscience workforce development—across industry, education, and government—is a shared vocabulary of techniques, educational activities, skill sets, and other elements that go into educating and training bioscience workers. Today, the biosciences tend to be very fragmented, with organizations living within their own domain and developing their own ways of characterizing skills, job requirements, and educational competencies. This fragmentation exists even within broad subsectors of the biosciences, so employers can vary greatly in their use of terminology, as is the case between hospitals and research organizations in characterizing laboratory science activities. Similarly, in the educational sector, there is no shared terminology across the breadth of bioscience degree programs.

Achieving this common vocabulary is not a simple undertaking, but it begins by cataloguing bioscience education and training terminology used by various stakeholders and comparing and contrasting terms. The proposed Arizona Bioscience Industry-Education Council should guide this activity.

Action 2: For identified fields of biosciences, focus on developing industry-driven skill standards translated into core curricula to ensure comprehensive, high- quality, and responsiveness program efforts.

It is recommended that Arizona follow the model of Washington State in cultivating a framework for bioscience program development based on industry working with educators and state leaders to assess skill needs, evaluate current programs, design curricula, and place students into jobs.

This skill-based framework can more cost effectively support new program development, while ensuring that graduates are properly trained for real-world positions. It also enables close "program" collaborations across different levels of education.

Funding is required for developing skill standards in particular areas of focus. The following are recommended as the first two primary skill development areas:

1) Laboratory sciences spanning healthcare and research lab environments
2) Biomedical production involving line production through quality assurance and regulatory compliance.

These skill standards should be developed under the auspices of the bioscience industry-education council and supported by the analytical capabilities of a proposed specialized university-related labor market research unit (see Strategy Four and actions on ongoing strategic assessment).

Action 3: Pursue shared-use approaches for deploying program resources statewide.

Shared approaches to skill standards and curricula will not be sufficient for Arizona to effectively deploy resources for bioscience workforce development. There is a key need for shared-use approaches for costly facilities and equipment. Core instructional facilities should be established for multiple institutions to use in a shared fashion—perhaps even co-listing common courses. In addition, many states are having success with mobile labs, often referred to as "biobuses." In California, under the Biotech Initiative of the Community College System, seven mobile laboratories have been put in the field during the past three years, each costing a minimum of $12,000 initially and $3,000 to $5,000 annually to maintain. Approximately 12,000 students annually have been exposed to hands-on fundamentals in biotechnology lab protocols through these labs. Maryland is having similar success with a biobus targeted to rural high schools in western Maryland.

Instructors are another key resource to be shared. Arizona needs to take advantage of distance learning approaches so that hard-to-find bioscience instructors can reach students across the state. This is particularly important for rural communities in Arizona, which may have a specific need for a bioscience program (e.g., because of an expanding local hospital or to serve the needs of agricultural businesses), but otherwise cannot support a full-time program.

Action 4: Dedicate funding for recruitment of topflight bioscience graduate students to Arizona.

The decline in Ph.D. and master's graduates in the biosciences is a troubling sign and a missed opportunity for Arizona. With the advancement of basic research activities in the biosciences, there is a clear opportunity for graduate students to serve in research labs and as a source of future postdocs.

A steady or increasing number of graduate students is also important for attracting future bioscience workers to the state. As Arizona's bioscience industry matures, it will be competing for more and more high-end scientific talent. Robust graduate programs can ease the strain of recruiting these high-end scientific workers to Arizona, since many will have roots in the state.

Arizona research universities have much to offer bioscience graduate students, with rising research programs and strong interdisciplinary tradition in education. Nevertheless, the market for bioscience graduate students is a highly competitive one, and attracting graduate students requires substantial scholarships and stipends that can be a drain on university resources.

It is proposed that a statewide scholarship for graduate bioscience education be developed to augment university resources on a matching basis. As a goal, the number of graduate students should increase at the same rate as the overall bioscience research base in the state.

Action 5: Develop a clearinghouse capability to broaden communications across students, employers, educational institutions, and parents on bioscience careers, educational opportunities, and requirements.

To ensure the ability to conduct outreach, marketing, and career awareness activities, it is important for Arizona to invest in a clearinghouse capability. This clearinghouse involves developing ongoing capacities to collect, present, and distribute information on bioscience careers, educational opportunities, and job requirements. More specifically, the needs to develop and maintain a Web site, integrate databases from divergent sources, survey educational institutions and employers, and develop and customize specialized presentation tools are expected.

Action 6: Strengthen K-12 math and science programs.

Students with basic math and science education are a prerequisite to developing a well-qualified talent pool in the biosciences. Arizona cannot succeed in bioscience workforce development without improving the achievement of students in the K-12 system. Suggested programs that can serve to raise the math and science level of students are Project Lead The Way (a pre-engineering program); after-school enrichment programs; and specialized academy, charter, and magnet programs.

Strategy Four: Conduct ongoing strategic assessment in a manner that institutionalizes the continued evaluation of bioscience workforce demand and alignment with supply to guide program and curriculum development and advance outreach efforts.

Background:

Ongoing strategic assessment is critical for bioscience workforce development to keep pace with the ever-changing environment of the highly innovative bioscience industry.

This study offers a snapshot of the demand and supply factors for the bioscience industry, but it should be used only as a baseline analysis. Regular follow-up on key trends is needed, as well as more detailed studies that can provide information on skill needs and gaps in Arizona, such as the proposed skills standards work. Indeed, a key theme running throughout this strategy—firmly captured in the vision and mission of bioscience workforce development in Arizona as well as all the other strategies—is the value of timely and quality information gathering.

Arizona's current preparedness for supporting this need for ongoing strategic assessment is suspect. From an access to data perspective, this project encountered certain limits in accessing basic occupational data commonly used in other states for workforce planning activities—such as the distribution of occupations by broad industry sectors.

Even more important is the lack of an organizational capacity in Arizona to easily conduct ongoing strategic assessment. As revealed by interviews with bioscience executives and educational leaders, there are no well-established connections across the bioscience employer community and the bioscience educational institutions to guide and support ongoing strategic assessment.

Best Practices:

Surprisingly, timely and quality assessment of bioscience workforce demand and supply is not a typical cornerstone of other states' efforts in bioscience workforce development. Across nearly all of the benchmark states, bioscience workforce efforts are relying on interactions with limited numbers of specific bioscience employers, often only one or two key firms, to plan and develop their programs.

The two notable exceptions to this pattern of limited ongoing strategic assessment are California and Washington State. The skill-standard-based approach used by Washington State has been discussed previously. Institutionalized through the formation of the Northwest

Biotechnology/Biomedical Education and Careers Consortium, this impressive effort truly ties together education, industry, government, and labor. It will be interesting to see whether Washington State can maintain this effort over time.

California has taken a less comprehensive approach, by making ongoing strategic assessment a key function of regional centers formed by the state's community college system. These regional centers have the responsibility to collect information from bioscience firms through a combination of surveys and direct employer involvement.

Actions for Strategy Four: Ongoing Strategic Assessment

Action steps are recommended for ongoing strategic assessment in two primary categories:

1) The proposed intelligence-gathering tools to be deployed
2) The proposed organizational approach to building consensus, guiding intelligence gathering, and applying the results.

The specific actions in these two categories are as follows:

- **Develop ongoing occupational and skill needs of employers, using regular vacancy surveys, occupational profiling, and other techniques.**
- **On a periodic basis, complete surveys of bioscience workers to learn their educational and training needs.**
- **Develop a specialized labor market research capability under the guidance of the bioscience industry-education council.**
- **Using the forum of the bioscience industry-education council, convene regular industry-education dialogues to discuss trends and issues arising across bioscience fields.**

Action 1: Develop ongoing occupational and skill needs of employers, using regular vacancy surveys, occupational profiling, and other techniques.

Building off of this baseline analysis of demand and supply factors, Arizona should publish, at least once a year, comprehensive occupational data linked to educational trends. Arizona should also focus on using the occupational data that it collects. Basic analysis of the occupational structure of bioscience subsectors is needed, including evaluating the changes in that structure within the state and comparing it to national trends.

Of particular importance is the growing use of vacancy surveys pioneered in the state of Minnesota and, with support from the U.S. Department of Labor, now further developed with survey forms, automated survey methodologies, and data capture and analysis software. Not only do these vacancy surveys capture specific occupations in demand, they can collect intelligence on wage levels, length of vacancies, and educational and work requirements. These vacancy surveys can be used more broadly, but, for the purposes of this effort, should initially focus on the subsectors within the bioscience industry, including university research laboratories.

More intensive follow-up reviews of the skill needs and gaps in the biosciences should be undertaken, building off of the vacancy survey. These reviews can include more detailed analyses of the skills required for vacant positions and large occupational categories within the biosciences to track skill upgrading needs.

Longer term, another key analytical tool that can be developed in concert with ongoing state labor market efforts would be to gain insights into the value of specific degree programs by tracking the labor market experiences of graduates. This requires linking databases from employer data payroll and social security files and must be done in a highly confidential manner. Such an analysis approach has been successfully used in Maryland to help measure the impact of specific educational and workforce initiatives.

Action 2: On a periodic basis, complete surveys of bioscience workers to learn their education and training needs.

Employers are not the only customers of the bioscience educational and training efforts. Current employees are also key customers. To aid in the development and evaluation of educational offerings, it is important to conduct an annual survey of employees to identify the types of career training and skill development they would like (specific courses, certificate/degrees), how and where that training should be provided (Internet-based, evening/weekend classes, location), and emerging issues that affect their career advancement.

Action 3: Develop a specialized labor market research capability under the guidance of the bioscience industry-education council.

Given the need for stronger research capabilities to support ongoing strategic assessments, it is suggested that a specialized unit be developed that can work under the guidance of the bioscience industry-education council, access primary data from the state's Labor Market Information Office, and perform tasks under the basic confidentiality standards of that office.

The state's Labor Market Information Office would retain the responsibility for primary data collection for payroll, occupational data, and the proposed new vacancy survey. The new specialized bioscience labor market unit would be responsible for conducting more focused surveys, such as on skills and employee needs.

Action 4: Using the forum of the bioscience industry-education council, convene regular industry-education dialogues to discuss trends and issues arising across bioscience fields.

Surveys and data analysis alone will not be sufficient to develop an ongoing strategic assessment. Forums of bioscience employers, educators, and current employees are needed to help interpret and refine the analysis of trends and issues.

It is recommended that a series of structured focus groups be undertaken, culminating in an annual bioscience workforce summit. As part of this summit, key findings, program developments, and future initiatives can be discussed.

Strategy Five: Establish an economic development focus that positions bioscience workforce development as a proactive tool for economic growth for the state.

Background:

A skilled, technology-based workforce is becoming more and more recognized as a central ingredient for supporting and sustaining economic development in today's advanced knowledge-based economy. In the day-to-day world of economic development, a region's capacity for cutting-edge, effective technology education and workforce development programs is a marketable asset that can make a difference in attracting outside investment and gaining expansion opportunities of existing businesses.

Arizona is in the midst of building its capacity to support bioscience cluster development. The state's roadmap for bioscience development is moving from concept to program design and implementation. Despite the critical importance of access to talent and workforce skills for bioscience development, most states fail to integrate workforce development as a key component of their overall bioscience economic development program—treating it more as a side issue than as a centerpiece. Arizona, given its unfolding effort, has a unique opportunity to strategically and proactively create a bioscience workforce development capacity to support its economic development objectives.

The following are some key issues for Arizona:

- Given the state's close proximity to California—perhaps the world's premier center for emerging bioscience industries—how can it develop a qualified workforce to be competitive for a share of that growing bioscience activity?
- How can the state leverage the growing presence of postdocs in Arizona as an economic development engine for growing emerging and new businesses and attracting new industry investments in higher-end bioscience commercial research enterprises?
- How can the state accelerate the development of a senior management talent pool to support the growth of emerging and start-up companies, particularly in emerging bioscience research areas, which in turn can accelerate more job growth for the future?

Best Practices:

The leading benchmark state in pursuing technology workforce development as an economic development tool to be packaged with other key incentives and resources is Georgia. In particular, the Georgia Intellectual Capital Partnership Program (ICAPP) serves as the economic development arm of the University of Georgia System. ICAPP offers employers its Advantage Program, which supports an existing or prospective Georgia company in working with a college or university to design curricula and courses of study to prepare students for specific knowledge jobs at that company. The company must commit to hire each ICAPP graduate participating in the program. As an example of ICAPP at work, Monsanto took advantage of the ICAPP Advantage Program and worked with Augusta State University to develop bioproduction-skilled workers, building upon the local expertise in the chemical industry and applying it to the production of a new synthetic growth hormone that increases milk production in cows.

Actions for Strategy Five: Establish an Economic Development Focus

The following action steps are recommended for establishing proactive connections to economic development:

- Develop and market bioscience workforce capacities targeted to specific bioscience industry segments within niche areas of bioscience activity where Arizona has broad-based competitive advantages.

- Provide matching funds for the development of specific company-based curriculum and program needs to be served through postsecondary institutions based on guarantees of jobs.
- Establish programs targeted to postdocs serving at Arizona academic institutions as prospective industry scientists and entrepreneurs.
- Develop a pilot biomanufacturing program in Arizona as a lead investment for targeting recruitment of biomanufacturing facilities to the state.
- Provide relocation assistance and other services to help in the recruitment of senior business executives and scientists by emerging and start-up bioscience firms.

Action 1: Develop and market bioscience workforce capacities targeted to specific bioscience industry segments within niche areas of bioscience activity where Arizona has broad-based competitive advantages.

Arizona needs to target its workforce and broader bioscience industry development efforts toward specific bioscience industry segments within the industry subsectors of commercial research and testing, medical devices, pharmaceuticals, agricultural chemicals and biotech, and hospitals and medical labs. This can include considering supply chain relationships, where Arizona can either fill in missing suppliers or use its supplier base to attract final goods producers. For instance, Arizona can build off of its strong optics capabilities to develop more in-depth knowledge of medical imaging requirements for industry.

This effort requires hands-on mapping of firms and their capabilities, and linkages with research organizations in Arizona; identification of national supply chain relationships; and ongoing dialogue with industry and relevant researchers.

Action 2: Provide matching funds for the development of specific company-based curriculum and program needs to be served through postsecondary institutions based on guarantees of jobs.

It is proposed that Arizona develop its own capacity, modeled after the Georgia ICAPP, to provide matching funds to support developing specific postsecondary programs based on employer needs linked to new job hiring. This approach has particular merit for states, such as Arizona and Georgia, that are ramping up their bioscience bases and seeking to establish key footholds in emerging fields.

This capacity allows workforce development to be a meaningful complement to business development activities. Unlike traditional customized training programs, it helps build postsecondary institutions by supporting curriculum development, professional development of faculty, and the development of specialized instructional labs. This capacity also encourages postsecondary institutions to be proactive in reaching out to the local bioscience industry to meet their specific educational and training needs. Finally, by linking these matching funds to specific job hires, it provides a high degree of accountability.

Action 3: Establish programs targeted to postdocs serving at Arizona academic institutions as prospective industry scientists and entrepreneurs.

Arizona has a key opportunity to leverage the significant hiring of postdoctoral scientists across the base of bioscience research organizations to develop a highly sought-after talent pool for industry needs, including emerging and start-up companies. Unlike tenured faculty, postdoctoral scientists are not necessarily committed to careers as faculty. Their focus is primarily on serving as research scientists, working on specific grants.

It is recommended that Arizona reach out to these postdoctoral scientists—and also graduate students and assistant faculty—to expose them to seminars and counseling on entrepreneurship, meet-and-greet events with the bioscience industry in Arizona, and other networking events of the bioscience industry. The goal is to help raise the entrepreneurial skills of postdocs, while also establishing broader links to the Arizona bioscience industry. Similar types of efforts are under way at institutions such as the University of Pittsburgh Cancer Center and Johns Hopkins University.

Action 4: Develop a pilot biomanufacturing program in Arizona as a lead investment for targeting recruitment of biomanufacturing facilities to the state.

In benchmarking California, it became apparent that the bioscience industry base in that state is moving into a next generation of development involving the manufacturing of biologics-based therapies on a significant scale. The California biotechnology base is maturing as its research and clinical trials activities advance into newly approved products.

Nationally, Genetic Engineering News (August 2002) reports that the current total pharma market is $390 billion, of which biologics accounts for 7 percent. By 2006, the total pharma market is expected to increase to $550 billion, of which biologics will account for $70 billion—a growth rate for biologics of 15 to 20 percent per annum. Moreover, approximately one-third of the entire new drug pipeline is now biologics.

The manufacturing of biologics involves complex scale-up manufacturing processes, requiring specialized skill sets. As noted earlier, industry analysts at McKinsey see a "biologics-manufacturing talent shortfall: the industry faces a looming shortage of the highly trained people needed to design, build and operate facilities [with] experienced process-development scientists and engineers, validation engineers, quality assurance personnel and plant managers are already in short supply."[9]

Key industry analysts expect to see a serious mismatch between who controls capacity to produce biologic-based pharmaceuticals and who needs the capacity. And, an emerging niche of contract biomanufacturing is arising to serve the needs of maturing biotechnology companies that lack the competencies to engage in full-scale production.

Given the proximity of California to Arizona, and the history of advanced manufacturing migrating to Arizona, targeting biomanufacturing activities may be a critical business development focus for Arizona. Biomanufacturing activities can serve an important role in the future development of Arizona's bioscience cluster and ensure that the state is able to gain the long-term benefits of not only research but high-value manufacturing activities.

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[9] Mallik, A., Pinkus, G., and Sheffer, S. "Biopharma's Capacity Crunch," *The McKinsey Quarterly 2002 Special Edition: Risk and Resilience.* McKinsey & Company, 2002, pp. 9-11.

On a limited scale, perhaps in concert with the needs of existing bioscience companies in Arizona, it is proposed that investments in biomanufacturing education and training programs be undertaken. Financing mechanisms for scale-up facilities to support and attract such investments to Arizona also will be a key complement.

Action 5: Provide relocation assistance and other services to help in the recruitment of senior business executives and scientists by emerging and start-up bioscience firms.

At the intersection of bioscience workforce development and economic development is the ability of Arizona to serve as a talent magnet, especially for hard-to-find senior bioscience business executives and scientists. While the long-term goal is for Arizona to grow its own talent, in the near term it is crucial that the state be able to attract these senior business executives and scientists. As identified in the focus groups, key issues about the quality of K-12 education in Arizona are important for attracting many of these senior bioscience workers, especially those with young families. More broadly, Arizona needs an active effort to assist businesses, research institutions, and other organizations in recruiting and relocating technology professionals and their families to the region. This effort can include helping to defray key relocation costs such as real estate taxes, helping to find suitable neighborhoods, and addressing special needs.

Moving Toward Implementation

This detailed strategic assessment of Arizona's position in bioscience workforce development offers tangible strategies and actions based on an integrated analysis of demand and supply factors and informed by best practices found in other states.

This strategic assessment is not the answer, but rather a baseline and blueprint for engaging more fully the broad stakeholders in Arizona. As mentioned earlier, the timing for this strategic assessment is opportune given the continued focus in Arizona on moving toward policy design and implementation of a broad bioscience cluster development initiative for the state. Arizona has a chance to make workforce development an integral part of that effort.

Critical Actions

Of the 26 action steps identified, 11 are noted as critical. These critical actions are essential if Arizona is to accomplish its vision of a demand-driven bioscience workforce system that emphasizes access to bioscience careers for Arizona citizens. They are as follows:

- Establish a statewide bioscience industry-education council to foster strong partnerships, involving ongoing industry guidance on program offerings and career pathways.
- Prioritize the development of bioscience programs based on a systematic process that aligns the demand and core skill sets in existing and emerging career pathways with ongoing educational program offerings and curricula.
- Design 2+2+2 career preparation programs rather than stand-alone degree efforts.
- Offer specific bioscience career awareness activities in K-12 involving enriched educational experiences with experiential learning opportunities.

- Work with industry to create customized retraining programs for current nonbioscience workers who demonstrate an aptitude to enter bioscience careers.
- Develop a shared, common vocabulary on bioscience workforce terminology.
- For identified fields of biosciences, focus on developing industry-driven skill standards translated into core curricula to ensure comprehensive, high-quality, and responsive program efforts.
- Pursue shared-use approaches for deploying program resources statewide.
- Strengthen K-12 math and science programs (Project Lead The Way, enrichment activities, etc.).
- Using the forum of the bioscience industry-education council, convene regular industry-education dialogues to discuss trends and issues arising across bioscience fields.
- Develop and market bioscience workforce capacities targeted to specific bioscience industry segments within niche areas of bioscience activity where Arizona has broad-based competitive advantages.

Immediate Actions

But, as the old adage goes, "actions speak louder than words." It also is important that Arizona seize the opportunity to accomplish "immediate" actions that can be implemented within a 6- to 12-month period to demonstrate progress and build momentum.

These seven immediate actions are identified as part of this strategic assessment:

- Establish a statewide bioscience industry-education council to foster strong partnerships, involving ongoing industry guidance on program offerings and career pathways.
- Offer specific bioscience career awareness activities in K-12 involving enriched educational experiences with experiential learning opportunities.
- Ensure that personalized services for minority, economically disadvantaged, and at-risk students found in K-12 and community colleges are continued as students progress at the four-year and graduate levels.
- For identified fields of biosciences, focus on developing industry driven skill standards translated into core curricula to ensure comprehensive, high-quality, and responsive program efforts.
- Develop ongoing occupational and skill needs assessment of employers, using regular vacancy surveys, occupational profiling, and other techniques.
- Using the forum of the bioscience industry-education council, convene regular industry-education dialogues to discuss trends and issues arising across bioscience fields.
- Develop and market bioscience workforce capacities targeted to specific bioscience industry segments within niche areas of bioscience activity where Arizona has broad-based competitive advantages.

SUMMARY

If Arizona can move forward on these initiatives and use the demand and supply side intelligence gathered by this study to guide new program developments, then it will have a strong bioscience workforce component to its overall bioscience roadmap effort. This analysis sees Arizona's workforce development strategy being driven by an understanding of its demand needs and ensuring that the supply generated by educational and training institutions is aligned with these demand requirements. Given the important role that talent pools are playing in advancing the knowledge economy and particularly the biosciences, it is expected that this investment in bioscience workforce development can pay significant dividends in the years ahead, while being realistically balanced by the needs of bioscience employers.

Appendix A: Survey Methodology

The web-based survey that was used to analyze the bioscience industry's demand for labor in Arizona was designed utilizing several data sources. First, a general examination of labor demand surveys was conducted. This task enabled Battelle to ensure the design of the bioscience workforce survey incorporated relevant questions that would provide the critical information necessary in which to observe unique labor market forces occurring in Arizona.

Second, Battelle explored several databases to ensure that the population to be survey adequately represented the Arizona Bioscience industry. The Dun & Bradstreet Marketplace database was the primary company directory used to identify companies. Marketplace also happens to be the main source of data used in previous Battelle analyses of the Arizona Bioscience industry. Several other databases were utilized to augment the D&B company directory including Corptech, The Arizona Hospital and Healthcare Association member list, and several member lists assembled from various Arizona bioscience trade organizations. The compiled survey population resulted in 1,195 establishments. This population had a combined employment of 55,285.

Firms were contacted initially through a mass mailing. Battelle was assisted in this activity by the Maricopa, Yavapai, and Pima Community Colleges as well as the Arizona Department of Commerce. Follow-up phone calls were initiated as second phase of contact in order to increase the number of responding companies. 296 establishments, representing those with 9 or more employees, were contacted by phone to request their completion of the survey. These firms represented 96% of Arizona's current bioscience employment base.

The survey design highlighted 13 prevalent bioscience job functions:

1. Research Scientist
2. Research Technician
3. Medical Care Laboratory Technician
4. Engineering – Product Development
5. Engineering – Process Development
6. Engineering Technician
7. Quality Assurance/Control/Validation
8. Manufacturing & Production
9. Technical Support (Logistics, Documentation, etc)
10. Regulatory Affairs
11. Health/Bio-Informatics
12. Forensics
13. Marketing & Sales

These job functions took into consideration the wide-ranging industry activity within the biosciences. Respondents were asked to answer the survey by indicating the employment and educational attainment level of each bioscience job functions as it applied to the establishment's operations in Arizona. A full copy of the survey can be found in appendix B.

Analyzing the results of the survey, interviews, and focus groups revealed that many of the job functions initially identified in the survey required workers to possess similar capabilities. For example several interviews indicated that research technicians and medical care lab technicians although performing different tasks, were required to possess many of the same skills. The indication that these job functions had many similarities made it clear that these job functions should be analyzed in conjunction.

It was understood from the demand analysis that job skills drive the demand for labor within different functional areas. Therefore categories of job functions with similar skill sets were created. The categories of job functions enabled Battelle to understand how certain job functions operated together and affected the demand for labor. The full analysis of the demand for labor by bioscience job categories is found within the main section of this document. A more detailed demand analysis by individual job functions is found in Appendix C.

Appendix B: Arizona Bioscience Workforce Needs Assessment Survey

This survey has been commissioned by a broad coalition of educational institutions and the Arizona Department of Commerce to ensure that Arizona has a qualified and available skilled workforce to serve the growing bioscience cluster, and an educational infrastructure to generate the required mix of skilled workers. Battelle Memorial Institute, which served as the strategic planning team for the state's overall Bioscience Strategy efforts, has been engaged to develop a more detailed assessment of the state's bioscience workforce needs and assist us in putting in place the specific strategies and actions to meet these industry-driven needs.

DIRECTIONS

- Start by answering **Part A** (on this page) and then complete **Part B** and **Part C** on the following pages.
- Please respond **before May 2nd**. Your cooperation will allow us to complete this survey in a timely manner.
- Surveys can be filled out via the Internet: **www.maricopa.edu/workforce/biosurvey.html**
- If you have any questions contact:
  Steve Kiefer
  Fax: (480) 731-8210
  Phone: (480) 731-8207
  Center for Workforce Development
  Maricopa Community Colleges
- **No data identifying individual firms, directly or indirectly, will be published or released.**

Part A

Company Name:
Contact Name:
Title:
Address:
Telephone Number:
Fax Number:
E-mail Address:
Website:
Primary Product or Service:
Main Activities in Arizona:
Number of Years in Business:
Total Number of Employees:
New Hires in Last Year:

Part B

A	B	C	D	E
Job Functions (Please classify individuals into the job function that most represents the majority of their activities.)	Number of Existing Workers	New Hires Last Year	Current Vacancies	Expected Hires in Next Two Years (including vacancies)
Research Scientist*				
Research Technician*				
Medical Care Lab Technician				
Engineering – Product Development or Research				
Engineering – Process Development				
Engineering Technician				
Quality Assurance/Control/Validation				
Manufacturing & Production				
Technical Support (Logistics, Documentation, etc)				
Marketing & Sales				
Regulatory Affairs				
Health/Bio Informatics				
Forensics				
Other				
Other				

*** The research scientist and research technician job functions include those individuals involved in medical, agricultural, environmental, and chemical fields.**

Part C

A	F						G	H		
Job Functions	**What Educational Level is usually required?** (Can choose more than one)						**Would you hire someone directly out of school or training program?**	**What experience is usually required?** (Can choose more than		
	No diploma	**High school/GED**	**Voc. Training/Cert.**	**2 year degree**	**Bachelor's degree**	**Advanced degree**		**Some work exp.**	**Exp. in related field**	**Exp. in this occupation**
Research Scientist*							Yes No			
Research Technician*							Yes No			
Medical Care Lab Technician							Yes No			
Engineering – Product Development or Research							Yes No			
Engineering – Process Development							Yes No			
Engineering Technician							Yes No			
Quality Assurance/Control/Validation							Yes No			
Manufacturing & Production							Yes No			
Technical Support (Logistics, Documentation, etc)							Yes No			
Marketing & Sales							Yes No			
Regulatory Affairs							Yes No			
Health/Bio Informatics							Yes No			
Forensics							Yes No			
Other							Yes No			
Other							Yes No			

- **The research scientist and research technician job functions include those individuals involved in medical, agricultural, environmental, and chemical fields.**

Appendix C: Key Job Functions

Several different data sources were utilized to identify major bioscience job functions.[1] However within each job function there exists a great deal of variability. Both the survey and industry interviews revealed that each job function has many different levels of competency. Different levels require different educational requirements, work experience, and responsibility. Therefore it must be understood that this analysis of bioscience job functions does not examine specific skill sets at each entry level for a particular job function. Rather skills common across the job function were analyzed to guide academic professionals. Educational leaders will need to pinpoint specific levels of key job functions in order to design effective educational programs.

Table C-1: Survey Results for Job Functions

Job Functions	Number of Existing Workers	New Hires Last Year	Current Vacancies	Expected Hires, 03-05	Percent of Expected Hiring to Existing Workers
Product R&D Engineer	385	30	15	34	9%
Research Scientist	342	59	23	132	39%
Medical Lab Technician	1,272	267	119	341	27%
Research Technician	344	81	25	160	47%
Forensics	65	16	4	34	52%
Manufacturing & Production	1,502	147	62	251	17%
Engineering Technician	337	27	6	30	9%
Process Development Engineer	244	14	10	28	11%
Marketing Sales	634	93	38	60	9%
Technical Support/ Documentation/Logistics	550	89	15	77	14%
Quality Assurance/Validation	317	43	21	31	10%
Regulatory Affairs	53	3	6	13	25%
Health/Bio-Informatics	45	4	1	11	24%

Employment Size

- Large: employment ≥ 500
- Sizable: 500 > employment ≥ 200
- Small: employment < 200

Employment Growth

- High Growth: employment increase ≥ 150
- Growing: 150 > employment increase ≥ 50
- Marginal: employment increases < 50

[1] United state Department of Labor, Industrial Occupational Surveys (Connecticut/Pittsburg), and dry run survey with clients and steering committee

Research: *Key Job Functions*

Research Job Functions	Number of Existing Workers	New Hires Last Year	Current Vacancies	Expected Hires, 03-05	Percent of Expected Hiring to Existing Workers
Product R&D Engineer	385	30	15	34	9%
Research Scientist	342	59	23	132	39%

Product Research and Development Engineers: This job function is the largest research job function. Respondents reported 385 people are employed as product R&D engineers. Though this level of employment is sizeable, projections from the survey indicated that the product R&D engineering function is marginally growing.

Product R&D engineering is expected to experience the slowest employment increase of all job functions over the next two years. Establishments forecast that the job function will grow by only 9 percent between 2003 and 2005. The projection is that only 34 new jobs will be added to the current employment base. This employment increase, relative to the increases of other job functions, is only marginally above what is needed to fill current vacancies.

Though the product R&D engineering function has a relatively low vacancy rate, the marginal growth that is expected by establishments will result in a very small net gain in employment. Currently the job function has a vacancy rate that is 3.9 percent of the existing employment base. However, the existing vacant positions comprise 44 percent of the expected new hires. Therefore, the product engineering job function is expected to only experience a net gain of 19 new employees by 2005

Product R&D engineering jobs tend to have high educational and work experience requirements. The survey demonstrated that a large number of establishments require new hires to have a minimum educational attainment level of a bachelor's or advanced degree. New hires are also expected to have a high level of work experience directly related to the field. Stringent skill requirements and marginal growth positions the product R&D engineering job function as one of the more exclusive bioscience job functions.

Research Scientists: This sizeable job functions is one of the high growth bioscience occupations. Currently, the research scientist function maintains an employment level of 342 according to the bioscience survey. Respondents indicate that between 2003 and 2005, the research scientist job function will add 132 new hires. This increase represents 39 percent of the current employment base. This predicted growth is responsible for the increasing share of bioscience employment within the research category.

Even with a higher than average vacancy rate, the forecasted growth for the research scientist function will more than compensate exist unfilled positions. Presently, the research scientist job function experiences a vacancy rate of 6.7 percent. Assuming vacant positions would be the first to be filled, the large projected employment increase will result in a net gain of approximately 109 new jobs.

The project new jobs will typically have a very high educational requirement. Respondents indicate that new hires will for the most part be required to hold some sort of advanced degree. Relative to other job functions, the survey reveals that the research scientist job function has the highest educational attainment requirement. In addition, respondents report that new hires should also possess a significant level of work experience that is in direct relation to the research position. The implication of these requirements which are concentrated at the higher end of the spectrum may suggest that within the research scientist job function there are very few differing skill levels.

Laboratory Technologists/Technicians: *Key Job Functions*

Laboratory Tech Job Functions	Number of Existing Workers	New Hires Last Year	Current Vacancies	Expected Hires, 03-05	Percent of Expected Hiring to Existing Workers
Medical Lab Technician	1,272	267	119	341	27%
Research Technician	344	81	25	160	47%
Forensics	65	16	4	34	52%

Medical Care Lab Technicians: Responding establishments indicate that the medical care lab tech job function is the largest occupation in the laboratory technician category. Medical care lab techs are also the second largest of all bioscience job functions. The survey revealed that 1,272 people were employed as medical care lab techs. This particular job functions is not only the major driving force steering the demand of laboratory oriented workers, but is also having a tremendous impact on overall demand for bioscience labor.

The medical care lab tech job function is growing at a faster rate than any other job function. The survey indicated that the medical care lab tech job function added the greatest number of jobs within the last year. The job function added 267 jobs, which represents 21 percent of the current employment base. The next two years are expected to see the rate of new hires to increase to 27 percent, adding 251 jobs. At the present rate of employment increase, medical care lab tech will be come the most dominate bioscience job function in Arizona.

The medical care lab tech function also possesses the greatest share of job vacancies across all bioscience job functions. Respondents that employ medical care lab techs report that 119 positions have currently been left unfilled. The 9.3 percent vacancy rate is the highest among all job functions.

Though expected new jobs will fill the exist gap, the high vacancy rate suggest a significant mismatch in the supply and demand for medical care lab techs. The level of unfilled positions is noteworthy because the survey indicates that this particular job function is the most pervasive among establishments. The survey reveals that 46 percent of respondents employ medical care lab techs.

The pervasive nature of the medical care lab function contributes to diverse educational and experiential requirements. Though a high concentration of establishments responded that an education beyond a 2 year degree is not required, a significant number of establishments require a minimum of a bachelor's degree and some even require an advance degree. The broad range of educational requirements suggests that within the medical lab tech job function there exist several levels employment activity.

Examining the experience requirements supports this finding. Establishments report that experience in the medical care lab tech field, experience directly related to the field, or no experience at all is acceptable. The large and wide-ranging nature of the medical care lab tech job function makes it one of the primer bioscience job functions. The job function is well positioned for future program development focus.

Research Technician: Respondents report that this job functions, though not presently very large, is expected to experience one of the fastest growth rates over the next two years. The survey reveals that the research technician function is a sizeable occupation. The job function employs 344. Between 2003 and

2005, the job function will add 160 new hires. This would represent an increase that is 47 percent of the current employment base.

The increase of new hires is very important when it is examined in connection with the relatively high vacancy rate. Though the number of actual vacancies is small, in comparison to the relatively small employment base, the vacancy rate is fairly large. Respondents indicated that 25 vacancies presently exist. This presents about 7.3 percent of the base employment. However, the new jobs created as a result of the forecasted new hires will more than compensate for the existing labor market mismatch.

The survey reveals that as new jobs are added establishments will require a mix of education and work experience. Respondents indicate that requirements for the research technician function range across the educational spectrum similar to the characteristics of the medical care lab tech function. However, unlike the medical care lab tech function, establishments typically have educational requirements for the research technician function that call for bachelor's and advanced degrees. Though positions in the research technician function exist at levels below the bachelor's level, these openings are not as prominent among the respondents. The variability of education and work experience combined with employment growth presents great deal of development opportunity for this particular job function.

Forensics: This job function is the smallest among the occupations in the laboratory technician category. According to the survey, the forensics job function only employs 65. Although respondents expect an increase in new hires over the next two years, the actual increase is marginal in comparison to other job functions. The survey indicates that 34 new hires will be added in the next two years.

The forensics job function reports a small employment figure in part due to the fact that the occupation is one of the more highly specialized bioscience job functions. Only 14 percent of respondents reported forensics employment. No other job function among the survey respondents is as concentrated as the forensics job function.

Establishments that reported employment for the forensics function typically require less than a bachelor's degree. Concurrently, these respondents also require a high level of experience directly related to the field. However, with so few establishments reporting employment in the forensics function, it is difficult to get a true sense of the educational and work experience employers require of new hires.

Production: *Key Job Functions*

Production Job Functions	Number of Existing Workers	New Hires Last Year	Current Vacancies	Expected Hires, 03-05	Percent of Expected Hiring to Existing Workers
Manufacturing & Production	1,502	147	62	251	17%
Engineering Technician	337	27	6	30	9%
Process Development Engineer	244	14	10	28	11%

Manufacturing: This particular job function is the dominate job function within the production category. Manufacturing is also the largest of all bioscience job functions. The current level of employment stands at 1,505 among responding establishments. It is also a job function experiencing one of the largest employment increases of any job function.

Over the course of last year, 147 new manufacturing jobs were added. This growth trend is projected to persist. Between 2003 and 2005, manufacturing is expected to grow by 17 percent. The total number of new jobs added will equal 251. This is the second greatest increase of jobs. The increase in new jobs combined with a relatively modest occurrence of job vacancies indicates that manufacturing demand for labor is being sufficiently met by current labor supply.

Manufacturing jobs has a below average job vacancy rate. The survey indicated that presently responding establishments are experiencing a 4 percent vacancy rate. Approximately 25 percent of new hires will go to fill existing vacant positions. This means that according to respondents there will be a net gain of 189 workers, over 75 percent of expected new hires.

The liberal educational and work experience requirements contribute to the amply supply of labor. Compared to all other bioscience job functions, the manufacturing job function has the most unrestrictive educational requirements. The majority of establishments responded that typically new hire are not required to possess a post-secondary degree. The low educational attainment requirements combined with the willingness to hire direct from school implies that employers are engaged in a significant amount of worker training. This presents a possible opportunity to develop training programs for employers that may not have the resources to provide new workers the training they may need to ensure product quality.

Engineering Technician: This job function represents the second largest job function within the production category. Although engineering technicians are substantially fewer in number than manufacturing workers, the job function is still considered relatively sizable. Respondents reported that engineering technician employment stands at 337.

The engineering technician job function is a modestly growing job function. Respondents report that this job function is forecasted to add 30 new jobs over the next two years. This job function is also experiencing a low vacancy rate of 1.8 percent. The implication is that although the demand for the engineering technician job function will be met over the next two years, the job function is not a major contributing bioscience employment position.

Though small in size, respondents revealed that the engineering technician function mirrors the manufacturing job function in terms of the requirements for education and work experience. Establishments that employ engineering technicians responded that they tend to seek new hires with a minimum of a two year associates degree. The survey also showed that employers have a willingness to hire direct after the completion of the program.

Process Development Engineers: This is the smallest of the job functions categorized as production oriented work. According to the survey, employment is 244. Relatively, process development engineers are still considered to be sizable job function although at the lower end of the spectrum.

Much like the engineering technician job function, process development engineering is a marginally growing job function. Respondents indicate that over the course of the next two years, the job function will grow by 11 percent but add only 28 new jobs. A large portion of these jobs will be used to fill existing gaps in the job function. The 10 existing vacancies equate to 36 percent of new hires.

The process development engineer function differs not only in size to the other production job functions but also in educational criteria for new hires. The survey demonstrated that establishment seeking to hire for a process development engineer function generally require candidates to hold a minimum of a bachelor's degree. However in keeping with the production job category trend, establishments indicated that new hires are typically hired upon the completion of the degree program.

Management Support: ***Key Job Functions***

Management Support Job Functions	Number of Existing Workers	New Hires Last Year	Current Vacancies	Expected Hires, 03-05	Percent of Expected Hiring to Existing Workers
Marketing Sales	634	93	38	60	9%
Technical Support/ Documentation/Logistics	550	89	15	77	14%
Quality	317	43	21	31	10%
Regulatory Affairs	53	3	6	13	25%
Health/Bio-Informatics	45	4	1	11	24%

Marketing & Sales: This job function constitutes the bulk of the management and support category of bioscience work. According to the survey, marketing and sales function has a large employment base. Across respondents 634 people are presently employed.

Marketing and sales is also one of the most common job functions among respondents. Survey indicated that 46 percent of establishments indicated some level of marketing and sales employment. Although a large and pervasive job function, the demand for the sale and marketing functions is not expected to increase significantly. Within the span of two years, the job function is expected to add 60 new jobs. This increase represents a 9 percent increase form the current base of employment.

The indication from the respondents is that new employees hired for marketing and sales positions should typically have a bachelor's degree. Though hires will be made below the bachelor's level, few employers seek individuals with an advanced degree. Rather, it seems that employers would prefer a high level of direct work experience than an individual with an advanced degree.

Technical Support/ Documentation/ Logistics: This job functions is a large bioscience related occupation. Respondents revealed that 550 people were employed as technical supporters. Technical support is a growing job function but is projected to grow at a slower rate in the coming years. According to the respondents, over the next two years the job function is expected to grow by only 14 percent, adding 77 new jobs. Last year alone respondent reported that 89 jobs had been added. Being at the lower end of the growing spectrum implies that technical support is not one of the high priority job functions in the near term future.

Similar to the majority of job functions categorized as management support, the educational requirements of the technical support job function tends to be less stringent than other job functions. Employers that responded to the survey revealed that an advanced degree for the most part is not required of new hires. Respondents typically require a minimum of a bachelor's degree. Some establishments require even less educational attainment.

Quality Assurance/Validation: Though not a large employing job function, the quality assurance function is considered to be sizeable with an employment level of 317. Over the next two years the quality assurance function is project to experience marginal growth, adding only 31 new employees.

The survey indicated that the quality assurance function is one of the more common job functions across responding establishments. The job function existed at 44 percent of the establishments that responded. As pervasive job function, the significance of the total employments size is diminished because of the fact that the quality assurance job function is so pervasive. The indication is that although many establishments may possess a quality assurance job function, few are employed at each job site.

Extensive employment across several establishments combined with the educational and work experience requirements, reveals that the quality assurance job function tends to be very specialized. This job function tends to require a minimum requirement of a bachelor's degree. Some employers even require new hires to possess an advanced degree. In addition, respondents indicated that it is important that individuals possess a relatively high level of work experience within the field of quality assurance. These factors demonstrate that the quality assurance job function is a technical position.

Regulatory Affairs: This is one of the smallest bioscience job functions. The survey indicated that the regulatory affair function employed only 53 people. In addition, the job function is only growing marginally. Taking into consideration both last years and forecasted new hires, the regulatory affair function is averaging approximately only 5 new hires a year.

The low rate of new hires combined with the a very high requirement for directly related work experience, places the regulatory affairs function as one of the most specialized bioscience job functions. Establishments indicate that new hires must have a degree of experience that is specifically associated to the field of regulatory affairs. This is high when considering that respondents typically require new hires to possess a minimum of a bachelor's degree.

Health/Bio-Informatics: This is the smallest bioscience job function. According to respondents, the job function only employs 45. The health/bio-informatics job function is also projected to have the smallest employment increase between 2003 and 2005. The survey indicated that establishments expect to only have 11 new hires over the course of the next two years.

The job function also has one of the most wide-range educational requirements. Respondents indicate that there is no preferred level of educational attainment. This may signify that the health/bi-informatics function is a job function that hires at several different levels depending upon the specific work requirements.

Appendix D: Bioscience Related Degrees

Bioscience Related Degrees	
Agricultural & Plant Sciences	**Biotech & Medical Products**
Agricultural Plant Pathology	Bioengineering & Biomedical Engineering
Agricultural Plant Physiology	Biological Tech./Technician
Agriculture/Agricultural Sciences, Gen.	Biomedical Engineering-Related Tech.
Agriculture/Agricultural Sciences, Other	Biometrics
Agronomy and Crop Science	Biopsychology
Botany, General	Biostatistics
Botany, Other	Biotechnology Research
Entomology	Genetics, Plant and Animal
Horticulture Science	Medicinal/Pharmaceutical Chemistry
Plant Breeding and Genetics	Neuroscience
Plant Pathology	Pharmacology, Human and Animal
Plant Physiology	
Plant Protection (Pest Management)	**Environmental Sciences**
Plant Sciences, General	Ecology
Plant Sciences, Other	Energy Management & Systems Tech./Techn.
	Environmental Science/Studies
Agricultural Animal Sciences	Forestry and Related Sciences, Other
Agricultural Animal Breeding & Genetics	Forestry Sciences
Agricultural Animal Health	Range Science and Management
Agricultural Animal Nutrition	Soil Sciences
Agricultural Animal Physiology	Solar Tech./Technician
Animal Sciences, General	
Animal Sciences, Other	**Food & Nutrition Sciences**
Dairy Science	Food Sciences and Tech.
Poultry Science	Foods and Nutrition Science
	Medical Dietician
	Medical Nutrition
	Nutritional Sciences

BIOSCIENCE RELATED DEGREES: CONTINUED

Bioscience Related Degrees	
Biology & Related Fields	**Medical Sciences**
Biochemistry	Anatomy
Biological and Physical Sciences	Basic Medical Sciences, Other
Biological Immunology	Dental Clinical Sciences/Graduate Dentis
Biological Sciences/Life Sciences, Other	Epidemiology
Biology, General	Health and Medical Biostatistics
Biophysics	Health Physics/Radiologic Health
Cell and Molecular Biology, Other	Medical Anatomy
Cell Biology	Medical Biochemistry
Evolutionary Biology	Medical Cell Biology
Marine/Aquatic Biology	Medical Clinical Sciences (M.S., Ph.D.)
Microbiology/Bacteriology	Medical Genetics
Misc. Biological Specializations, Oth.	Medical Immunology
Molecular Biology	Medical Microbiology
Parasitology	Medical Molecular Biology
Pathology, Human and Animal	Medical Neurobiology
Physiology, Human and Animal	Medical Pathology
Radiation Biology/Radiobiology	Medical Pharmacology & Pharmaceutical Sc
Toxicology	Medical Physics/Biophysics
Virology	Medical Physiology
Zoology, General	Medical Toxicology
Zoology, Other	Physiological Psychology/Psychobiology
Chemistry & Material Sciences	**Medical Laboratory Technician**
Analytical Chemistry	Cytotechnologist
Chemical Engineering	Medical Laboratory Technician
Chemistry, General	Medical Technology
Chemistry, Other	
Engineering Science	
Inorganic Chemistry	
Material Engineering	
Materials Science	
Organic Chemistry	
Physical and Theoretical Chemistry	
Polymer Chemistry	
Polymer/Plastics Engineering	

Appendix E: Bioscience Workforce Case Studies

California

California is generally recognized as a global center for the biotechnology industry. According to the Ernst & Young's Global Biotechnology Report for 2002[2], the United States had 342 publicly owned biotechnology companies in 2001, one-third of which were located in California. It is also estimated that one-third of the nation's biotechnology workers are in California. California's biotechnology industry includes a maturing cluster of companies in San Francisco, rapidly growing clusters in San Diego and Los Angeles/Orange County, and smaller clusters of companies in Davis and Sacramento.

Given that California has one of the oldest clusters of biotechnology companies—San Francisco traces the origins of its biotechnology sector back to the founding of Genentech in 1976—it is not surprising that the state and its regions have an established history of programs and activities designed to train workers for positions within the biosciences. The nature of these programs and the nature of the skills required by the bioscience sector vary by region based in part on the stage of development of the industry. In the Bay Area and, to a somewhat lesser extent, in the San Diego region, although the industry started with a focus on research and development, more and more companies are moving into production, thereby requiring production workers with skills in biomanufacturing. Jobs in California's bioscience industry, however, continue to require a spectrum of skills ranging from basic scientific research in laboratory settings, to manufacturing biotechnology products, to business functions such as sales and marketing, finance, regulatory affairs, quality assurance, human resources, and procurement.

Overview of California Activities

Focus of Bioscience Workforce Development Programs

California's bioscience workforce training is provided primarily by California's community colleges and four-year colleges. While some programs are available at the high school level, they are not widespread. The community college system provides the bulk of technical, hands-on training, while college extension services and continuing education provide professional development courses that allow professionals from other fields to move into positions with bioscience companies. The four-year colleges provide a variety of undergraduate and graduate degrees in many bioscience areas. One criticism of the university programs is that they do not provide sufficient lab training for their students. This is due to a lack of lab facilities to accommodate the large numbers of students completing degrees in biology and related fields.

In January 2002, San Diego Workforce Partnership Inc. completed a strategic workforce development plan that provides a blueprint for meeting the workforce development needs of the region's bioscience industry. The plan, which was developed by a coalition of industry,

[2] Ernst & Young, *Beyond Borders: The Global Biotechnology Report 2002.*

education, and training leaders, included the following recommendations with regard to education and training strategies to meet current workforce needs:

- Educational providers should offer more courses in quality assurance and quality control.
- The University of California at San Diego and San Diego State University should incorporate more laboratory skills into their curricula.
- Educational providers and employers should increase their level of interaction in applying for grants and coordinating student internship opportunities.
- Employers should play a key role in the delivery of sales education for the industry.
- San Diego State University should offer an M.B.A. program with a focus on biotechnology.

In 2003, the California Legislature's Select Committee on Biotechnology held hearings on workforce development issues. It was suggested at the hearings that California needs "decreased reliance upon foreign nationals, increased hands-on and university laboratory experiences, new specialized training facilities, new academic-industry partnerships, new professional MSc. Degrees, creation of new industry focused and involved Professional Doctorates, and increased deployment of on-line courses and degrees."[3]

Nevertheless, the development of bioscience programs is not always smooth. The highly successful San Diego Community College Biotechnology Program, which has been a model and catalyst for other community colleges from Delaware to Austin to Salt Lake City to New Hampshire, was eliminated due to lack of funding and broader institutional support. It is expected that, with massive budget cutbacks pending, California's efforts in bioscience workforce development may be negatively impacted.

Range of Program Development Across K-20 and Extent of Articulation and Program Linkages

In the San Diego area, discussion is underway between the community colleges and universities to determine how to make the best use of limited time and resources by focusing on key strategic areas. It would appear that most of the efforts to coordinate activities have occurred within each system, e.g., among community colleges and among California State University (CSU) campuses, rather than across systems. However, there is an effort to coordinate activities across institutions at the regional level.

The most active articulation is between community colleges in California and the CSU colleges. Sixty percent of the students coming into CSU come from the community college system. In bioscience fields, CSU campuses have begun to offer more specialized bioscience degree programs, which enable more compatible articulation from biotechnology associate degree programs at community colleges.

California also boasts of active K-12 programs and increasingly is developing programs to link with post-secondary institutions. The Bay Area Biotech Educational Consortium brings together six independent Bay Area K-12 local school-industry partnerships, which focus on providing mobile labs, teacher training, and other specialized programming. The Berkeley Biotechnology Education, Inc. (BBEI), which operates as an independent entity, reaches approximately 100 students annually and establishes a stepping stone to further educational and employment opportunities. Recently the City College of San Francisco has been

[3] A. Stephen Dahms. "Biotechnology Education: Possible Road Maps for Workforce Development in Biocommerce Clusters, Including Institutions of Higher Education: Results of Legislative Hearings on the Current and Future Workforce Needs of California's Biotechnology Industry." *Biochemistry and Molecular Biology Education* 2003 31:197-202.

developing a “Bridge to Biotech” program to reach out to economically disadvantaged high school students to encourage them to pursue opportunities in the biosciences.

Student Recruitment

Initial efforts in Northern California to train students for careers in the biosciences focused on creating tech prep programs in which students would take high school courses for two years and then transfer to community colleges to complete bioscience degrees. With the exception of one program in Berkeley, BBEI, efforts to create such programs were not particularly effective. (BBEI is described below.)

Educators have had much greater success in reaching out to students already at the community college to interest them in bioscience careers and in providing training for people who are returning to school from the workforce. Students at the community college level tend to be people who are already in the workforce or are needing specific skills training to pursue positions with bioscience companies. The community colleges provide the bulk of hands-on lab training for bioscience workers in California. There is a great need for training for people who already hold a bachelor’s or master’s degree but come to the community college to acquire up-to-date skills needed in the workplace. The total number of students enrolled in the biotechnology programs of California Community Colleges in any semester is about 1,100.

A Bridge to Biotech program has been initiated at the high school level in the San Francisco area that will seek to equip students with the science, math, and English skills needed to prepare them to pursue bioscience training at the community college level.

As many as 50 percent of the students enrolling in bioscience classes offered by the University of California-San Diego’s (UCSD’s) Extension Service hold advanced degrees. Many of these individuals are professionals (e.g., doctors, lawyers) looking to make mid-career changes. Another source of students for these programs are pre-professional postdocs who require training in technical skills before seeking a position in industry. UCSD Extension enrolls about 1,500 students in the biosciences annually.

Use of Strategic Assessments of Supply and Demand for Particular Bioscience Occupations

One of the functions of the Biotechnology Centers, which are part of California Community College’s Biological Technologies Initiative (Biotech Initiative—see description under “Leading Program Activities”), is to collect information from bioscience firms to determine skill needs. This is done at the regional level through a combination of surveys and personal contact. The Central Coast Biotechnology Center, for example, which is located at Ventura College, conducted a biotechnology workforce census in 1998. The survey collected data on the characteristics of the bioscience companies in the region, the education and specific knowledge skills required of entry-level workers, skills of current workforce needing upgrading, availability of training programs and preferred training delivery methods, and projected hiring needs.

The California State University Program for Education and Research in Biotechnology (CSUPERB) conducts an annual national survey of H-1B visas in the biotechnology industry to determine worker shortages and therefore where foreign workers are needed. Nationally H-1B visa holders are sought in highly sought-after areas such as analytical chemistry, instrumentation specializations, organic synthesis, product safety and surveillance, clinical research/biostatistics, bio/pharm quality, medicinal chemistry, product scale-up, bioinformatics, applied genomics, computer science, cheminformatics, pharmacokinetics, and pharmacodynamics. A survey done by BIOCOM, San Diego’s bioscience industry association, showed that 31 percent of the companies and 6 to 8 percent of the bioscience workers in the San Diego region have HB-1 visas, indicating a shortage of workers. Interestingly, 85 percent of those with HB-1 visas are graduates of U.S. colleges and universities and most remain in the United States over the long term.

Industry Involvement

Industry involvement has played a critical role in the growth of California's bioscience workforce development programs. Working through trade associations and one-on-one with individual campuses, California's bioscience companies have contributed to the development of curricula, provided sites for internships, donated equipment, and provided a source of faculty. By and large, the business community has found that the four-year colleges and the community colleges have been responsive to working with the companies to meet their needs for trained workers. Established companies, such as Amgen, Genentech, and Baxter, work very closely with California's community colleges.

Linkages to Broader Economic Development

California's workforce development programs have a long history of being linked to state and regional economic development strategies. In the 1980s, legislation was passed making economic development a primary mission of California Community Colleges. As a result, the Community College system established an economic development program, known as ED>Net. The Biotech Initiative is a component of this program. Revised legislation, which took effect in January 2003, identified strategic priority areas for the community colleges, one of which is biotechnology.

California, at both the state and regional level, has targeted industry clusters for development. In San Diego, bioscience is one of nine industry clusters that the region is seeking to develop. In January 2002, the San Diego Workforce Partnership, Inc., released a strategic workforce development plan for the region's bioscience industry cluster. The Workforce Partnership is a nonprofit organization that manages public and private contracts to connect people with jobs or training to meet employers needs. The Partnership is responsible for developing the strategic plan that directs San Diego's Workforce Investment Act efforts.

Development of Curriculum

Responsibility for developing curriculum rests with the individual colleges; however, California State University, the University of California, and the California Community Colleges all have programs that support the development of bioscience curriculum and undertake efforts to make curricula available to schools and faculty. CSUPERB administers a program that awards grants of up to $15,000 on a competitive basis for curriculum development. The curriculum must be related to

- Biotechnology, with an industrial focus in the applied sector
- New technologies and biotechnological innovation
- Tech training activities—K-14 enhancement and outreach
- Distributed modes of training and learning.

CSUPERB's budget for curriculum and infrastructure development grants for fiscal year (FY) 2003–2004 is $180,000.

The University of California's Biotechnology Research and Education Program also awards grants that can be used to support the development of new programs. The City College of San Francisco, which serves as the national office for the National Science Foundation (NSF)-funded Bio-Link, has established a curriculum and instructional materials clearinghouse. A primary role of the California Community College Biotechnology Centers is to make faculty aware of and to share curricula. The Community College Biotech Initiative has a Biotech Curriculum Collection available in pdf format on the Web (www.cccbiotech.org and www.ccbcweb.net,) with 51 courses or lab protocols.

Despite these efforts, however, program managers noted that individual faculty and colleges still tend to want to develop their own curricula. One of the recommendations that came out of this year's Hearings of the Select Committee on Biotechnology is the creation of a permanent fund that would award competitive matching grants for the development of specific, industry-focused courses to be distributed to California's 139 public institutions of higher education.

Role of Experiential Learning Activities

California's bioscience workforce development programs make extensive use of externships. Internships are actively pursued, typically as capstone activities at the end of programs for qualified students. BIOCOM, which has 250 members, usually places about 40 interns annually. Their members report that it is difficult for small companies to take interns given the time commitment involved. California's larger biotech companies participate fully in internship programs.

One program that fully integrates experiential learning with classroom instruction is that provided by BBEI. BBEI is a private nonprofit organization founded in 1992 to train youths from traditionally underserved populations to enter biotechnology employment. The program grew out of an economic development agreement between the City of Berkeley and the Bayer Corporation. Bayer committed more than $1.4 million in start-up and implementation funds. Now many other biotech companies, universities, and public labs participate in the program. Core funding is provided through foundation grants, with industry paying for the internship and co-op work experiences.

BBEI has developed a fully integrated program that involves targeted high school courses in the eleventh and twelfth grades, a paid internship between the two grades, a paid internship between high school and community college, four community college courses, and a paid year-long co-op work experience in industry while in college. The curriculum is developed by joint industry-high school/community college work groups.

Teacher Training Activities

Most of California's bioscience workforce development and education initiatives provide opportunities for teacher training. CSUPERB has undertaken a number of initiatives over the years to help upgrade the skill sets of California's community college faculty. In the early 1990s, CSU received a $1 million faculty enhancement grant from the NSF. The grant was used to (1) train university faculty in cutting edge technologies, including community college faculty, as appropriate, and (2) hold one- to two-week workshops targeted to community college faculty. While CSUPERB no longer has NSF support to conduct these activities, it continues to hold three workshops a year in which it provides training for community college faculty. CSUPERB also funds activities designed to network CSU, community colleges, and high schools. CSUPERB makes grant awards to cover the cost of faculty and student travel to participate in national and international biotechnology professional meetings and workshops.

A key objective of the Community College Biotech Initiative is to provide faculty members with training opportunities. Between 1998 and 2003 slightly more than 3,000 faculty members have attended training courses. Each of the seven mobile biotech labs throughout the state has workshops associated with it to train faculty members as trainers. University of California-Davis holds bioinformatics summer institutes for community college instructors only.

Funding of Labs and Equipment

Funds awarded to the six regional biotechnology centers can be used to purchase equipment, but the funds are very limited. In large part, biotechnology equipment of the centers and their participating community colleges is usually donated by private companies. Autoclaves, thermocyclers, deoxyribonucleic acid (DNA) sequencers, micropipettors, electrophoresis units, for example, have been collected by the Biotech Centers and given to community colleges. Four centers have fielded seven mobile laboratories in the past three years, each of which costs a minimum of $12,000 initially and $3,000 to $5,000 annually to maintain. Approximately 12,000 students annually have been exposed to hands-on fundamentals in biotechnology lab protocols through these labs.

Development of core facilities has been an integral part of CSUPERB's strategic plan from the beginning of the program. CSUPERB has provided support for five core facilities. While these facilities were planned to provide services to research faculty, they are being used more and more for enhanced training. In the future, there may be a need to develop more facilities primarily for training purposes. Development of core facilities requires a lead campus, which has faculty that can serve as principal investigators for an instrumentation proposal, to partner with six or seven other campuses. CSUPERB can provide financial support that in the past has been matched on a 1:1 basis and, more recently, on a 4:1 basis.

Key Success Factors

- **Extensive industry involvement.** All of California's bioscience programs emphasize the important role played by industry in identifying skill needs, helping to design curricula, providing positions for internships, and donating time and equipment.
- **Importance of work-related curricula and internships and co-ops.** Work-related, competency-based curricula and experiential learning opportunities help students to gain skills and experience and give industry the opportunity to see students as prospective employees.
- **Hands-on laboratory approach to curriculum taught by industry.** This ensures that students understand real-world work requirements and applications.
- **Programs need to be applied and interdisciplinary**. This is key to preparing students to work in biotechnology companies.

Barriers to Success

- **Perception in the biotech industry that those who work in a biotech company must have earned at least a bachelor's degree in a science.** This is changing, however, as the larger companies such as Genentech and Amgen directly hire the graduates of some of the community colleges with which they work.

- **Lack of knowledge** among potential biotech employers, employees, students, and faculty **of the biotech training that is available.**
- **Lack of sufficient resources and access to equipment** to train students in state-of-the-art methods.
- **Insufficient numbers of trained faculty members** and thus courses to meet the stated demand by industry personnel.
- **Lack of basic skills in biology, math, and English in the traditional community college population,** which hinders entry into two-year bioscience degree programs.

LEADING PROGRAM ACTIVITIES

California State University Program for Education and Research in Biotechnology (CSUPERB)

CSUPERB is a multicampus initiative created in 1987 to focus the resources of California State University on a system-wide basis on biotechnology. Since its inception, the program has made 180 grant awards for curriculum development, joint ventures with industry, and creation of new facilities. CSUPERB holds an annual symposium for faculty and students focusing on key development in biotechnology and provides funding for faculty and students to travel to national and international conferences and workshops. The program is tightly interfaced with industry. CSUPERB plays a catalytic role with the various CSU campuses, providing funds that can be used to hire new instructors and to create new technical programs.

Key Contact: A. Stephen Dahms, Ph.D., Director, San Diego State University, (619) 594-5578, sdahms@sciences.sdsu.edu

Size of Program: Current annual budget is $1.4 million, but the program is slated to grow to $12 million by 2009. It is hoped that the budget will increase to $5 million in the next 18 months**.** In addition to its state appropriation, CSUPERB receives about $5 million in matching funds and $6 million to $7 million in gifts on an annual basis.

Faculty: CSUPERB does not have faculty itself, it works to support the faculty at CSU's campuses.

Curriculum: CSU's 22 campuses offer a wide range of undergraduate, graduate, and continuing education programs in biotechnology, biochemistry, molecular and cell biology, microbiology, agricultural biotechnology, biotechnology entrepreneurship, regulatory affairs, biotechnology-related engineering, and bioinformatics. In many cases, emphasis in these areas is provided within the biology major. Examples of programs offered include

- B.S. and M.S. in biochemistry
- M.S. in molecular biology and microbiology
- B.S. and M.S. in microbiology
- M.B.A. specialization in biomedical regulatory affairs and management
- M.S. in regulatory affairs
- Pharmaceutical engineering major within College of Engineering and Computer Science

- B.S.E.E. with option in biomedical engineering
- M.S. in biomedical engineering.

Special Programs: CSUPERB manages several grant programs designed to support biotechnology research and education. They include

- *CSU Biotechnology Programmatic Development Grant Program.* This program provides grants of up to $15,000 to support the development of curricula, workshops, and short courses. Greatest consideration is given to projects that are multidisciplinary and multicampus and that promote academic industry linkages.
- *Faculty-Student Collaborative Research Seed Grant Program*. This program makes awards of up to $10,000 to young faculty to enable them to prepare grant applications for external research funding. All projects funded must have substantial involvement of students.
- *Faculty Travel Grants*. CSUPERB makes $500 awards to enable faculty to participate in national and international professional meetings and workshops related to biotechnology.
- *Biotechnology Student Travel Grants*. CSUPERB makes $900 awards to encourage students to present their biotechnology research findings at national and international professional meetings.

Facilities: CSUPERB operates five core facilities that serve faculty and students from all 22 CSU campuses. Core CSUPERB facilities include

- Microchemical Core Facility DNA lab located on the campus of San Diego State University (SDSU)
- Confocal Microscope Core Facility located at CSU Stanislaus
- A comprehensive X-ray crystallographic facility at the W.M. Keck Foundation for Molecular Structures at CSU Fullerton
- Macromolecular Structural Analysis Resource Center at SDSU (CSU's bioinformatics and genomics core research facility)
- Environmental Biotechnology Institute at Cal Poly San Luis Obispo (focus on bioremediation).

Industry Partnerships: CSUPERB operates an Entrepreneurial Joint Venture Matching Grant Program that provides $1,000 to $25,000 on a matching basis for promising entrepreneurial joint ventures. Projects must be a collaborative effort of a CSU faculty and other individuals or institutions and result in positive economic development impacts. The FY 03–04 budget for this program is $240,000.

Keys to Success:

- Extensive industry involvement.
- Need to understand and differentiate between workforce development and education. Workforce development has a zero to six-year time horizon, while education has a 10- to 18-year time horizon. Companies are interested primarily in workforce development programs.

UCSD Extension

UCSD Extension offers a certificate program in biotech manufacturing, regulatory affairs, bioinformatics, and drug discovery and development. The classes are for professional development. Most of the students have at least a B.S.; about 50 percent already hold advanced degrees. Often the students are transitioning into biotech from another industry or making a mid-career change. They include people with M.D.'s, J.D.'s, and other advanced professional degrees. Extension courses are very applied, but they are not lab-based. The community colleges provide most of the skills-based hands-on training. The Extension tries to provide skills not taught at the B.A. level.

UCSD does not provide much hands-on training. The problem is that the university has about 3,000 biology majors annually, so it's very hard to get them into lab-based classes.

Key Contact: Dr. Sharon Wampler, UCSD State Extension, Bioscience Director, (858) 964-1346, swampler@ucsd.edu.

Size of Program: About 1,500 people participate in Extension bioscience courses annually.

Faculty: The Extension uses people from industry to teach the classes.

Curriculum: For every program established, the Extension sets up an industry advisory committee. To determine which courses should be offered, the Extension works with networking and industry groups. It also uses workforce data on a macro level. The Extension is finding that the real need in the San Diego region is for people with B.S. and M.S. degrees rather than Ph.D.'s. and A.A.'s. There are plenty of the latter. Currently UCSD and the community colleges are discussing what each should be focusing on in terms of bioscience education and workforce development.

The Extension's programs are very applied and interdisciplinary. This is key because, within industry, the scientists have to deal with the business people, who have to deal with the clinical people, etc. They offer a medical chemistry course in which intellectual property is discussed; students have to understand these issues to work in drug development.

Facilities: Extension programs are not lab-based.

Industry Partnerships: Industry representatives participate on advisory boards that play a a key role in setting curricula. Individuals from industry serve as faculty.

Keys to Success:

- Industry involvement
- Focus on applied skills and interdisciplinary courses.

Courses are in demand; although a key issue for the university is in marketing its programs, an unaccustomed activity for most universities. They have no trouble finding faculty.

University of California Biotechnology Research and Education Program (UC BREP)

UC BREP is responsible for fostering integrated multidisciplinary research and training across the nine UC campuses, three national laboratories (Lawrence Livermore National Lab, Lawrence Berkeley National Lab, and Los Alamos National Lab), and the Agricultural Experiment Station. UC BREP primarily provides seed funding for the development of new programs. In a recent, extensive five-year peer review of the program, one reviewer commented, "UC BREP is a highly successful program as judged by the objective measures of dollars leveraged and students trained and as judged by industry satisfaction. Other benefits have also been realized in research funding and faculty collaborations."[4]

Key Contact: Martina Newell McGloughlin, (530) 752-8237, mmmcgloughlin@ucdavis.edu.

Size of Program: UC BREP receives a state allocation of $1.5 million annually. During FY 2002–2003, four proposals were funded for $1,180,000. These projects involved 20 graduate students, six postdocs, and 20 investigators.

From 1985 until 2002, UC BREP

- Awarded 135 grants, 108 of which were in science and engineering; 19 of which were in economics, business, law, and social science, and eight of which focused on public and K-12 education.
- Allocated $22.4 million that supported 789 graduate students and postdoctoral scholars.

Faculty: The program has no faculty of its own.

Curriculum: UC BREP can award funding for the development of curriculum at the campus level.

Special Programs: The following are examples of projects funded for 2001–2004:

- Support for a new interdisciplinary research and training program in nutritional genomics.
- Support for training graduate students in interdisciplinary research in the chemical, biomedical, and bioinformatics sciences. Long-term goal is to develop an interdisciplinary research and training program between the Department of Chemistry, the Department of Information and Computer Science, the School of Biological Sciences, and the College of Medicine at UC-Irvine to understand bimolecular interactions in complex biological systems.
    - Novel training program to produce Ph.D. students and postdoctoral fellows with unique interdisciplinary tools that will make them invaluable to the drug discovery and biotechnology industries in California.
    - Biotech training program that outlines a pathway to integrate concepts of biology, chemistry, materials, and engineering for graduate students working at the forefront of bio-nano-scale materials research.

Facilities: UC BREP does not provide funding for facilities.

Industry Partnerships: This program focuses primarily on university and lab faculty and researchers.

Keys to Success:

- The program provides small seed grants that have been used to leverage significant federal funding. It has allowed UC to stay at the forefront in the development of new areas of the biosciences.

California Community College Applied Biological Technologies Initiative (Biotech Initiative)

This initiative of the California Community College (CCC) System was created in 1997 to improve community college effectiveness in supporting biotechnology-related economic development in

[4] http://ucsystembiotech.ucdavis.edu/message.cfm, 4/28/2003

California. The initiative, which operates out of the Chancellor's office, is part of the Economic and Workforce Development Program of the CCC System. The Economic and Workforce Development Program was established by legislation, which was originally passed in the 1980s and has been amended several times (most recently by Senate Bill 1566, which became effective on January 1, 2003). The bill identifies strategic priority areas, one of which is biotechnology.

The initiative is run as a competitive grant program, with individual community colleges applying to be designated as the biotechnology center for their region. The Biotech Initiative includes six centers organized geographically with the mission of serving the needs of the biotechnology workforce in California. Each Center receives an annual grant of $178,875. The statewide office receives $135,000. Each Biotech Center must have an advisory committee made up of industry representatives.

The Centers facilitate communication among colleges and companies, coordinate faculty interaction with industry, and stimulate industry-education collaboration. The Centers operate job placement and student internship programs and develop core curriculum and academic support programs.

Specifically, the Centers

- Collect information from California biotech firms to determine biotech employee skill needs through surveys and by personal interaction with companies. (For an example of a workforce needs survey, see www.ccbcweb.net.)
- Facilitate economic development partnerships between regional economic development groups, local high schools, the California Technology Trade and Commerce Agency, and four-year educational institutions.
- Create and support connection between local industry representatives and community college faculty members who teach biotech courses.
- Support the community of biotech instructors regionally and statewide by gathering and distributing used biotech equipment and assisting in curricula development, marketing, and creating and maintaining mobile labs.
- Assist in placing students and faculty in internships and biotech program graduates in jobs.

The Northern California Biotechnology Center includes six community colleges that offer two-year biotechnology programs and serves the Bay Area. The Southern California Biotechnology Center is managed by the Center for Applied Competitive Technologies at San Diego City College. CACT-SD is one of 12 regional Advanced Technology Centers (ATCs) established by California to assist manufacturers in modernizing their manufacturing and production processes. The mission of ATC-SDCC is to "advance California's economic growth and global competitiveness through quality education and services, focusing on continuous workforce improvement, technology deployment and business development."[5]

Key Contact: Mary Pat Huxley, Statewide Director, (805) 648-8977, (800) 344-3812, pmhuxley@ednet.cc.ca.us

Size and Student Population: Of the 108 California Community Colleges, 32 offer either a specific course or full program in biotechnology. Another 24 colleges are beginning or implementing biotech courses. In additional, other colleges include biotechnology content in genetics, ethics, biology,

[5] http:www.cact-sd.org/about_us.html.

chemistry, math, robotics, heating and air conditioning, and information technology courses. The total number of students enrolled in the CCC's biotechnology programs in any semester is about 1,100. This does not include "successful non-completers," those students that receive the training that they need and are not interested in completing a degree or certificate program.

Faculty: Each of the community colleges that have or plan a biotech course or program has faculty members that have been connected with local industry. People from the biotech industry teach biotech lab classes, give lectures and seminars, and act as internship overseers for students.

Program/Curriculum: Each of the 108 CCCs offers the basic science courses—biology, chemistry, math, genetics, molecular biology, and statistics—necessary for biotech industry standards. The biotech centers conduct industry surveys to determine workforce needs, but each college determines its biotechnology curriculum. The Biotech Initiative helps the colleges meet industry needs by sharing industry standards with college faculty. The skill standards used come from three documents: (1) *Gateway to the Future: Skill Standards for the Bioscience Industry*[6], (2) *Biotechnology/Biomedical Skill Standards: Research, Development, and Manufacturing and Regulatory Affairs and Clinical Trials*[7]; and (3) *Biotechnology/Biomedical Skill Standards*[8] (Education Development Center, Inc.)

As an example of the type of curriculum offered, Ventura Community College offers certificates and associate degree programs in biotechnology. The curriculum includes

- Human Genetics
- Statistics
- General Chemistry
- Organic Biochemistry
- Organic Biotechnology
- Introduction to Biotechnology
- Field Botany
- Biotechnology Methods
- Plant Biotechnology Methods.

The Southern California Biotechnology Center has developed curricula for the following courses:

- Biotechnology Program New Module Format
- Easy Classroom Column Chromatography
- Nonradioactive Colony Hybridization to Detect a Foreign Protein
- Egg White Lysozyme Purification and Assay by Ion Exchange Chromatography
- Egg White Lysozyme Purification and Assay by Size Exclusion Chromatography
- Easy Classroom Polymerase Chain Reaction
- Enzyme Linked Immunosorbant Assay (ELISA)

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[6] Education Development Center, Inc., 1995.
[7] Berta Lloyd and Terryll Bailey, Washington State Board for Community and Technical Colleges, 2001.
[8] Ibid.

- DNA Sequence Analysis.

San Francisco Community College, which houses the Northern California Biotechnology Center, offers a one-year Biomanufacturing Certificate Program and a two-year Biotechnology Certificate. The Biomanufacturing Certificate Program includes classes in Elementary Algebra, Introduction to the Science of Living Organisms, Introduction to Medicinal Chemistry, and Advanced Medicinal Chemistry and Biotechnology.

Solano Community College offers a biotechnology production technician program that requires the following courses:

- Principles of Biotechnology
- Business and Regulatory Practices in Biotechnology
- Cell Culture and Protein Recovery
- Biotechnology Instrumentation
- Principles of Microbiology (4 units) or Principles of Cell and Molecular Biology (5 units)
- Intermediate Chemistry (4 units) or General Chemistry (5 units).

Facilities: The Biotech Centers use some grant funds to purchase equipment to share with regional colleges; however, the dollars that they have to work with are very limited. The centers also collect and distribute industry-donated supplies and equipment. Autoclaves, thermocyclers, DNA sequencers, micropipettors, electrophoresis units, for example, have been collected by the Biotech Centers and given to community colleges. Four centers have fielded seven mobile laboratories in the past three years, each of which costs a minimum of $12,000 initially and $3,000 to $5,000 annually to maintain. Approximately 12,000 students annually have been exposed to hands-on fundamentals in biotechnology lab protocols through these labs.

Industry Linkages: Industry representatives serve on both center and statewide advisory committees and make themselves available for queries and surveys throughout the year. The centers play a role in helping to place students and faculty in internship positions with biotech companies. In addition, some of the colleges have entered into partnerships with individual biotech companies. Each year, for example, 25 CC biotech students intern part-time at Genentech during the school year and full-time during the summer, with the expectation that they will be hired at Genentech after they complete their training,. IDEC Pharmaceuticals has entered into a partnership with MiraCosta College in Oceanside to educate and train more than 800 biomanufacuring workers over the next four years. Amgen and Baxter Healthcare often hire the graduates of the College of the Canyons, Ventura, and Moorpark College’s biotech programs.

Barriers:

- Perception in the biotech industry that those who work in a biotech company must have earned at least a bachelor’s degree in a science.
- Lack of knowledge among potential biotech employers, employees, students, and faculty of the biotech training available within the CCC System.
- Lack of access to sufficient equipment to train students in state-of-the-art methods.

- Insufficient numbers of faculty members and thus courses to meet the stated demand by industry personnel.

Keys to Success:

- Enthusiasm of faculty and center directors
- Perseverance
- Access to dollars

San Diego City College Biotechnology Program[9]

San Diego City College's biotechnology program became a flagship biotech program, which has been a model and catalyst for other community colleges from Delaware to Austin to Salt Lake City to New Hampshire. Unfortunately, this highly successful program was terminated due to lack of sufficient resources to meet demand. So many companies became involved with the program that the Program Manager could no longer keep up with the demand, and the College was unable to find the funds to support the program. The entire program was taught by industry professionals, with oversight, course evaluation, and followup conducted by the Program Manager, Dr. David Singer of San Diego City College. The program eventually covered all of Southern California. While their efforts were not based on a strategic assessment of supply and demand, they used newspaper articles to identify industries/companies that quoted local economic development agencies as to how many biotech companies were in the area.

Skills: Genetically engineered cells, bacteria, yeast, insects, mammalian, protein purification with focus geared toward production technician industries and other entry-level research technicians. While this was essentially termed "vocational" education versus academic teaching (by law community colleges can't offer upper-level training), the Program Manger essentially taught them as upper-level courses.

Key Contact: David Singer, (619) 388-3400, drhulk@aol.com

Size of Program: Before the program ceased, students with baccalaureate degrees were beginning to represent the majority to 100 percent of the program, and most were minority students. Dr. Singer also began recruiting students from nursing programs as well as other biology/medical-related career paths mainly because the students were in these programs because they did not realize what else was available (i.e., biotechnology).

Recruiting: After placing an advertisement in the class schedule catalogue and receiving a very large response, Dr. Singer had potential students speak with someone in the industry to find out more about it (they were given company tours, lab tours, etc.). In the last class at the school, the program had almost 100 percent baccalaureate students who interacted with 12 to 14 hiring managers who taught their classes. This was a very effective recruiting tool for students, which is likely why there was such a large number of four-year degree students in the program.

Faculty: The faculty was composed completely of industry professionals who simultaneously taught the classes and recruited students for their companies. This unique feature of the program also served as a very useful recruiting tool for students as students increasingly signed up for programs that they knew were taught by industry professionals actively recruiting competent students to work at their companies. This feature also acted as an effective training tool for the employers because they knew what they were

9 http://www.sdcity.edu/voctech/biol/

getting from the students and that they could train them appropriately to their needs. Faculty were paid a stipend of $40 to $45 per instructional hour.

Curriculum: The curriculum was developed with 80 people from 30 local bioscience companies. The classes were taught by the bioscience company representatives, with oversight and teacher/course evaluation by Dr. Singer. Students were essentially attending classes/lab 40 hours per week, including the class hours/lab/internship and studying.

Special Programs: They purposely did not initiate any articulation agreements with other schools because they wanted the people from their programs to go directly into industry. Dr. Singer mentioned that he has not seen much success in high school to college articulation programs and feels that the limited amount of money allotted for biotechnology activities would be better spent on more fruitful endeavors. Also, Salt Lake City College in Utah has hired someone from industry to train high school biotech teachers so that they can effectively train high school students in biotechnology. As a tie-in to local economic development initiatives, it received an EDNET grant (a state economic development grant) for its program for promoting ties between academia and industry.

Facilities: SDCC was the only production technician program without a facility for research; it used facilities of local companies for this research.

Industry Partnerships: Industry was not only significant to the success of this program—it was the driving force behind it with more than 30 companies involved at its peak. The entire faculty consisted of industry professionals; lab facilities were provided by industry; and 400 to 1,500 reagents were used during the course of the program, entirely covered by the companies involved. The program started with no money, and companies involved with the program covered virtually the entire cost. Before the program's end, Dr. Singer was able to establish a successful relationship with Dow Chemical, which would have provided $5,000 annually to the biotechnology program at SDCC. Additional corporate relationships also were beginning to develop with other local biotechnology companies before the program came to an end.

Keys to Success (what needs to happen):

- Working with companies that are committed to teaching the students relevant and cutting-edge skills and then hiring them upon graduation
- Need to have a full-time administrative person, instructor, and industry professional dedicated to the program.

Berkeley Biotechnology Education, Inc. (BBEI)

BBEI is a private, nonprofit organization founded in 1992 to train youths from traditionally underserved populations to enter biotechnology employment. The program grew out of an economic development agreement between the City of Berkeley and the Bayer Corporation. Bayer committed more than $1.4 million in start-up and implementation funds. Today, many other biotech companies, universities, and public labs participate in the program. Core funding is provided through foundation grants, with industry paying for the internship and co-op work experiences.

BBEI has developed a fully integrated program that involves targeted high school courses in the eleventh and twelfth grades, a paid internship between the two grades, a paid internship between high school and community college, four community college courses, and a paid year-long co-op work experience in industry while in college. The curriculum is developed by joint industry-high school/community college work groups.

The program has been highly successful in meeting its objectives. Approximately 95 percent of BBEI students are youths of color, and 60 percent are female. All graduates of the certificate program have been offered regular jobs after program completion, and 50 percent of these are continuing their education in A.S. or B.S. programs while employed. Many of the students are the first to graduate high school in their families, and most are the first to attend a postsecondary education institution.

Key Contact: Mary Alice Rathburn, Executive Director, (510) 705-5149

Size: Approximately 100 students annually participate in the program.

Faculty: Courses are taught by faculty at Berkeley and Freemont High Schools and at Laney College.

Program/Curriculum: Faculty work closely with BBEI's industry partners to design curricula. Skills taught include setting up and maintaining lab equipment, conducting routine tests, supporting researchers, and tracking data.

Special Programs/Features: This program is operated by a nonprofit organization and includes expensive work experience. It also is targeted to at-risk and disadvantaged youths.

Industry Linkages: BBEI's mission is to facilitate partnerships between industry and local schools. The program places students in internship and cooperative positions with as many as 40 government agencies, biotechnology companies, and health care institutions.

Keys to Success:

- Excellent support services to students, including mentoring from faculty and business lab coordinators; counseling on careers, job applications, and interviewing; and paid tutoring
- Work-related, competency-based curriculum and internships and co-op work experience that help students and give industry the opportunity to see students as prospective employees
- Focus on industry priorities by addressing real skill shortages, giving industry leadership in setting priorities, giving industry the opportunity to see students as prospective employees, and reducing recruitment and retention costs
- A tangible opportunity for students to succeed through defined career ladders, access to prestigious well-paying jobs, and paid internships and co-op work experience
- An independent governing body comprised of stakeholders, but separate from education institutions. BBEI has its own budget, has flexibility to adapt and change, and can negotiate agreements with various education institutions.

California: Industrial Biotechnology Instruction at Moorpark College

In 1994 Baxter approached Moorpark College, the local community college, for laboratory workers at its new scale-up facility manufacturing recombinant factor 8. In response to this request, Moorpark hired a former postdoc from the Salk Institute, who established a biomanufacturing program, which received support from NSF to outfit a very specialized hands-on biomanufacturing laboratory.

Key Contact: Dr. Maureen Harrigan, Professor of Biotechnology at Moorpark College, (805) 378-1400, mharrigan@vcccd.net

Size: 16 to 20 students per year. Heavily subscribed by broad range of students, 50 percent of whom have higher degrees and are returning for specific biomanufacturing training.

Faculty: Use industry to teach all specific biomanufacturing courses.

Curriculum: One-year program in biomanufacturing (after basic chemistry, biology, and math requirements met) features an applied curriculum designed by industry. The program includes courses on plant design, process support, cell culture/microbial fermentation, recovery/ purification, formulation/fill/packaging, quality control, environmental control, and validation. Twenty hours per week are taught in five-hour blocks involving a combination of classroom and hands-on laboratory work (see "Facilities" on instructional manufacturing lab).

Facilities: An instructional manufacturing laboratory that mimics the industrial environment is being set up, and scientists from industry are teaching the modules, guaranteeing that the technical training of students directly matches industry's needs. The facility includes a gowning room, cell culture lab, microbial fermentation, recovery and purification areas, analytical methods lab, buffer/media preparation, and glassware wash and storage area.

Industry Partnerships: These are at the core of the program—providing the idea for the program, designing the curriculum, teaching applied curriculum, and hiring graduates (100 percent placement rate). The program is led by two major employers—Baxter and Amgen (the largest employer in the county). Another 10 companies are actively involved, including support firms involved in filtration systems, etc.

There is no active internship program given the hands-on curriculum, close industry involvement in the program, and the fact that it is only a one-year program.

Special Programs: Attempts have been made to establish articulation arrangements. Students in secondary schools lack interest and are reluctant to meet prerequisite requirements. An articulation agreement is being established with secondary schools and universities to delineate a career path in biotechnology.

Keys to Success:

- Strong industry involvement
- Hands-on laboratory approach to curriculum taught by industry—ensures that students understand real-world work requirements and applications
- Willingness of college to hire a person with bioscience experience.

GEORGIA

Georgia has recently embarked on efforts to become the Southeast's leading bioscience center and be recognized among the nation's leaders. The state desires to build off of its world-class research and exceptional ability to translate research discoveries into new products and services. The industry in 2001 employed roughly 13,000 across 502 establishments throughout the state. Currently, Georgia's position in the biosciences indicates that the industry is in the early phases of development.

In January 2002, the state received final recommendations from the Battelle Memorial Institute[10] that identified a set of actions for the state to take in order to cultivate a robust bioscience sector. However, since the bioscience focus is a relatively recent emphasis of the state, there is no coordinated effort that comprehensively addresses the bioscience workforce issues.

Although the economic development strategy has yet to be fully implemented, articulating the areas of drug discovery and vaccine development, agriculture biotechnology, and medical treatments and devices allows workforce training managers and educational leaders to start to focus on specific niches of the bioscience industry. Several institutions in Georgia have taken full advantage of the state's increasing bioscience emphasis and utilized existing state incentives to bolster workforce education and training programs.

OVERVIEW OF GEORGIA ACTIVITIES

Focus of Bioscience Workforce Development Programs

The state currently possesses an infrastructure designed to cultivate new emerging technologies across all industries. These initiatives have a greater emphasis on spurring economic development projects rather than workforce development. However, these programs still have had an immense impact on statewide workforce training and education. The Georgia Research Alliance (GRA) and the University System of Georgia's (USG's) Intellectual Capital Partnership Program (ICAPP) are two programs that have had an influential effect on workforce development.

State institutions have capitalized on these existing initiatives and applied them to the identified bioscience niches, using a bottom-up approach to building workforce programs. Because these preexisting initiatives require industry to be involved in all technology developments, several of the bioscience workforce programs end up becoming a part of a broader economic development project. This environment has led several of the current bioscience workforce programs to take on uniquely local characteristics. Though seemingly appropriate from a standpoint of local industry labor needs, funding school programs or equipment as well as designing industry-accepted skill standards/curriculum are issues that are more efficiently dealt with at the state level.

Although Georgia possesses several existing technology development programs that institutions have been able to apply to bioscience labor issues, focusing exclusively on research technology excellence has not been enough to ensure the success of bioscience workforce programs. The existing mechanisms have

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[10] *A Strategic Framework to Make Georgia a Leader in the Biosciences,* prepared by the Technology Partnership Practice of Battelle Memorial Institute for the Georgia Life Sciences Summit, 2002.

centered mainly on higher educational institutions. Community college and K-12 institutions have taken advantage of state programs only by partnering with universities.

Though the existing state mechanisms have enabled institutions to be proactive in bioscience workforce program development, managers and directors of some programs have found that industry involvement with educational institutions is critical to create effective workforce programs based on new technologies. These individuals feel that in order to take full advantage of existing research-driven initiatives, the level of bioscience industry focused on technology development in Georgia must increase. Therefore, continuing to implement new workforce bioscience strategies beyond those already created may saturate the current market for bioscience research laborers.

Range of Program Development and Linkages

Bioscience workforce programs in Georgia mainly exist at community colleges and four-year academic institutions. Some outreach programs do exist between four-year universities and local K-12 institutions, but as mentioned above, the existing mechanisms of the state are geared toward higher education initiatives. However, local interactions and linkages between community colleges and universities are very strong.

Because programs tend to take on a local quality and emphasize certain technology developments as they apply to specific industry partners, community colleges and universities have worked together to help facilitate these local economic development initiatives. Linkages between these institutions also stem from the creation of transfer curriculum, developed to bridge students with associate degrees to universities and four-year colleges.

- As the state has moved to a bioscience industry focus, leaders among the community colleges have been developing curriculum for future bioscience workforce programs that, in part, build from some of their existing programs in medical and clinical technology. These institutions have worked with four-year institutions as well as the State Board of Education to ensure that the curriculum would pass both state and industry guidelines.
- Utilizing programs offered by ICAPP and GRA, colleges and universities have received a great deal of funding that has been used to transfer and commercialize new bioscience-related technologies. These efforts have allowed these higher education schools to create programs and curricula that specifically meet the needs of industry partners. Georgia's universities and four-year colleges also have developed an extensive array of educational programs on their own. Although quality degree programs and industry relationships are the two very important ingredients for bioscience workforce initiatives, as of yet there is no coordinated workforce strategy or plan that emphasizes the biosciences.

Student Recruitment

Several of the state's community colleges possess programs in the fields of medical and pharmacology technology. Though these programs are not precisely connected to developing a bioscience workforce, several educational leaders have indicated that these types of programs possess the students who would be most interested. These crossover programs are seen as a vital source of students once industry activity reaches a level of critical mass.

The universities and four-year colleges have had success enrolling interested students by partnering with industry on specific projects. These projects, using some of the economic development programs offered by ICAPP and GRA, are structured such that the industry partner invests in a college or university in return for seminars and curricula that train incumbent and future workers with skill sets specifically tailored to the company's needs. These types of partnerships, sponsored by the state, guarantee the colleges and universities prospective students for new programs that are designed to meet specific industry needs.

Linkage to Economic Development Strategy

The state of Georgia is in the initial stages of developing a strategic bioscience initiative. The bioscience industry is a wide-ranging sector of the state's economy. Georgia has begun to take steps toward understanding the unique nature of the industry in the state's economic environment. This approach helps the state to target its future initiatives, including assessing the labor needs of certain niches within the bioscience industry.

The economic evaluation Battelle performed on behalf of the GRA identified specific areas of research and industry activity in which Georgia has emerged as a major leader. The report identified strategic steps the state can take to further develop these core competencies. One of the factors the report covered was the recruitment of well-trained bioscience workers, clearly indicating a need for the state to address the labor needs of the industry.

Strategic State Assessment

Since the state of Georgia has not yet fully implemented a bioscience strategy, no specific statewide strategic assessment has been performed to evaluate the bioscience workforce needs of the industry. Even without a statewide industry needs assessment, current programs have conducted local needs assessments. To the extent possible, some institutions have analyzed the local and regional bioscience industry and have designed programs accordingly. Even though some institutions determined that industry activity in the local economy was insufficient to begin new programs, proactive steps were taken to prepare for future state-initiated industry developments. These institutions stand ready to implement state-approved programs and curricula.

Development of Curriculum

Existing programs stem from specific economic development projects and therefore were created to serve a very precise labor need of a particular industry partner. Curricula designed to serve narrowly defined economic projects have been successful in the short term, but the ability of these types of programs to translate to the needs of a broader market segment may fall short in the long term. Many managers and directors have recognized this issue and have thus decided to hold off on implementing more educational and training programs until the industry needs of the identified bioscience niches become more evident.

Role of Experiential Learning

The explicit design of current programs has made experiential learning an integral part of existing curricula. The strong relationship to local economic development projects explains why programs possess curricula that emphasize meaningful experiential learning opportunities. Some of the existing state economic initiatives require programs to have such learning opportunities if the program is to receive state funding support.

These learning experiences take many different forms. Internships are the most obvious form. Students also gain the benefit of experiential learning in the classroom. Programs are specifically tailored to meet the needs of industry, allowing classroom and lab environments to replicate real-life working situations. The intent is that, upon completing the program, students possess the practical skills necessary to obtain jobs as knowledge workers.

Teacher Training Activities

Teacher training has not been a major emphasis of programs. Since most initiatives occur at a high level within the academic world, most teachers already possess the skills and knowledge necessary to implement workforce education and training programs. Some outreach programs exist between higher educational institutions and K-12 schools, but not on a large enough scale to constitute a concerted effort.

Facility Funding

Facility funding has been perhaps the most apparent example of Georgia's effort to ensure quality education and training of the state's future workforce. However, these efforts on the state's behalf have primarily focused on higher educational institutions.

Often partnerships between industry and education require that schools upgrade their facilities in order to effectively collaborate with industry. The state has taken tremendous steps to create an educational infrastructure that will not only advance the educational attainment of students but also strengthen the ability of higher educational institutions to commercialize research and translate new innovations into market opportunities for industry.

Current funding mechanisms finance projects on the basis that industrial partners will provide matching funds. The size and scale of a potential partnership between the educational institution and private partners determine the state's portion. The GRA is among the most active initiatives in the state providing such funding programs. It has provided funding for 61 projects under the auspice of the Technology Development Partnership program since 1996. Companies such as Merial, Hewlett Packard, Lucent, BellSouth, Mitsubishi and AirSept have participated in various projects throughout the state.

Key Success Factors

A key factor of success has been to identify potential industrial partners. Cultivating relationships with private business has been a very effective way for programs to establish clear and concise workforce program goals and objectives. Institutions that engage in developing programs geared toward industry workforce needs have the assurance that program design and curriculum is in line with industry skill standards. Thus, program managers and directors are confident that students are receiving the necessary training to obtain employment.

Barriers to Success

The barrier preventing widespread success of bioscience workforce programs is that existing incentives are narrowly focused and as of yet uncoordinated. The emphasis on university research and the direct involvement of industry make it difficult to develop a systematic approach toward workforce development. The emphasis on research limits existing workforce development programs. Focusing strictly on research-driven initiatives limits the realm of possible gaps that may exist in the bioscience industry.

Absent the financial involvement of private corporations, workforce development specifically geared toward the bioscience industry receives little assistance. However, the state is still in the early stage of its strategic planning process. Bioscience industrial development has only recently become a state priority.

LEADING GEORGIA PROGRAM ACTIVITIES:

University of Georgia System

Intellectual Capital Partnership Program (ICAPP)

ICAPP is the economic development arm of the University of Georgia System. ICAPP has three initiatives currently underway throughout the state:

- ICAPP Access provides user friendly, "one stop shop" access that makes the resources of the University System easily available to Georgia businesses.
- ICAPP Innovations works with employers and the college and universities of the state to develop courses and degree programs that meet the needs of business.
- ICAPP Incentives helps businesses reduce their operation costs by reducing the cost of hiring and training employees. ICAPP Advantage and GeorgiaHire.com are two examples of ICAPP Incentives.

The ICAPP's development goals are broad in nature. The emphasis of ICAPP is to target all potential knowledge workers within the state's multiple industry clusters. Although the program is not structured to exclusively develop a bioscience workforce, the program by in large assures that programs developed at the state's colleges and universities coincide with industry needs, including the bioscience industry.

Key Contact: William Hearn, ICAPP Advantage , Program Director, Will.Hearn@usg.edu, (503) 614-7282

Size of Program: ICAPP is responsible for initiating all economic development projects at the 34 public colleges and universities within the University of Georgia System. In 2003 these 34 institutions accounted for 232,000 students. Presently, approximately 20 projects have been initiated under the ICAPP Advantage and 2 projects under ICAPP Innovations.

Program Specifics:

ICAPP Advantage

The focus of ICAPP Advantage is on cultivating and preparing knowledge workers for occupations in high demand and short supply in specific regional labor markets. These clearly stated objectives make it essential that the program take into account the skill needs of employers.

ICAPP has learned, for example, that 65 to 70 percent of Georgia's life science workforce has or needs a B.S. or B.A. degree to qualify for position openings. Therefore, ICAPP has structured its program to balance the needs of short-term training of incumbent workers and the longer-term development of the knowledge worker. Thus, USG institutions are encouraged to offer certificate programs, when possible, in addition to full degree programs.

Companies that utilize the ICAPP Advantage program receive the following benefits: reduction in hiring costs, acquisition of employees with skills specifically tailored to meet the unique needs of the local labor market, and reduction in the need to relocate labor from other regions.

A project must meet several requirements to be funded as an ICAPP Advantage project:

- The project must prepare people to be employed as knowledge workers. The employer must, in turn, create at least 10 new knowledge jobs that are strategically important to Georgia.
- There must be a documented shortage of this type of worker throughout the industry in the regional labor market, not only in an individual company.
- An employer and a USG college or university must work together to design a program of study to prepare students for specific knowledge jobs at that company. The company must commit to hire each ICAPP graduate in the job for which they were educated. Students must receive a grade of C or better in each ICAPP course to graduate.
- Instruction must be compressed into a substantially shorter time than usual. ICAPP students must be full-time students. Classes must be for academic credit. (A limited number of noncredit courses that specifically apply to an employer's proprietary information may be part of the ICAPP Advantage program.)
- When possible, graduates of the program may qualify for loan cancellation depending upon their salaries.
- Companies partnering with a USG institution to design a program are required to help fund new initiatives at the institution. The state of Georgia matches all funding at a rate of 2:1.
- The USG institution must certify that the education needs being addressed by the application cannot be met by existing programs at Georgia Department of Technical and Adult Education (DTAE) institutions in the service area.

Facilities: ICAPP will fund equipment purchases, but will not provide assistance for long-term infrastructure projects. The goal of the program is to ensure that the university or college takes immediate ownership of the program. ICAPP is seen only as the initiator.

Industry Partnerships: Industry is inextricably linked to ICAPP. All deals must have a realized benefit for business. The programs are not designed to further bolster university programs or degrees. The focus is economic development.

Keys to Success: Monsanto's partnership with Augusta State University is a specific example of the program. Monsanto expressed an interest in locating a new state-of-the-art production facility in Augusta to produce bovine somatotropin, a synthetically produced growth hormone that increases milk production in cows. The company collaborated with Augusta State University to educate 20 team leaders for the new facility. Faculty members from the school worked with engineers at Monsanto to develop the content for the new professional-development program for the incoming supervisors. Once the program had been developed, the school applied for ICAPP funding under the ICAPP Advantage program to help mitigate some of the costs. Today, Posilac, Monsanto's bovine somatotropin product line, is the largest selling dairy-related animal health product in the world.

In a second phase, Augusta State University intended to create a new educational track that would focus on the workforce needs of Monsanto. The goal was to build off of the local expertise in the chemical industry and apply it to the new niche market. The school had plans to educate 130 unit specialists in chemistry, biochemistry, and microbiology utilizing the ICAPP Advantage program. Unfortunately, due to an economic restructuring of the company and tightened regulation by the European Union, Augusta State University was forced to put those plans on hold.

The statewide effectiveness of the ICAPP Advantage program has had the direct economic benefit of a 15:1 return on the state's investment. According to a 1998 study,[11] the state's investment in the program has helped to bolster salary increases.

Athens Technical College

The Biotechnology Associate Degree Program

Biotechnology is an emerging field that is based on many fields, including biology, microbiology, biochemistry, molecular biology, immunology, genetics, chemistry, and chemical process technology. Research and development in biotechnology seeks answers and solutions that will improve human health, agriculture and food production, and environmental conditions. Recent innovations involving genetic engineering have had a major impact on biotechnology. Applications of biotechnology are diverse, including production of new drugs, transgenic organisms, and biological fuels; gene therapy; improved crops; and cleaning up pollution.

Technicians are employed by private, governmental, or educational laboratories that perform research in basic or applied science. Tasks are typically directed toward solving fundamental questions concerning the environment or the production and development of medicines and other useful materials. Biotechnology technicians may be involved in advanced laboratory techniques such as genetic engineering, molecular diagnostics, vaccine production, food safety, and environmental testing or work with important biological molecules.

Graduates may be employed as biological science technicians, chemical analysts, chemical technicians, or physical science technicians in government and university laboratories involving molecular biology, environmental work, food safety, waste water treatment, or agricultural engineering. Employment also is available in industrial and corporate organizations involved in pharmaceutical and vaccine production, biological and chemical processes, and agricultural and food processing.

Contact: Joseph E. Pyle, Program Director, Research Laboratory Technology; B.S., Valdosta State College; M.S., Ph.D., University of Georgia; (706) 355-5086, e-mail: jpyle@athenstech.org

Curriculum: The curriculum covers the basic principles of chemistry, biology, and microbiology; recombinant deoxyribonucleic acid (DNA); analytical chemistry; laboratory instrumentation; and growth, isolation, and characterization of microorganisms and cells and their components. Students receive training in basic plant and animal cell culture, recombinant DNA methods, immunological techniques, and purification and identification of important biological molecules.

The general studies component of the curriculum is designed to develop written, oral, and computational skills and provide breadth to the curriculum in the areas of humanities, behavioral sciences, and mathematics. The associate degree provides graduates with the opportunity for career mobility and facilitates continuing education at the baccalaureate level.

Key Courses:

- BIO 196 Medical Microbiology: This course is designed to provide the student with a foundation in basic microbiology with emphasis on infectious diseases.

[11] "Analysis of Georgia's Intellectual Capital Partnership Program," Economic Forecasting Center at Georgia State, 1998.

- BCH 201 Biology of the Cell: This course provides a study of the chemistry of living systems, including cell structure, biological molecules, metabolism, syntheses, and molecular genetics.
- BIO 203 DNA Molecular Laboratory: In this course, students learn fundamental techniques of genetic engineering, restriction analysis, plasmid isolation, preparation of recombinant DNA, construction of gene probes, and Southern blot analysis. In addition, students perform fundamental methods related to plant-based biotechnology.
- CHM 202 Instrumental Analysis: This course covers basic discussions of the theory of operation and analytical applications of ultraviolet-visible spectroscopy, infrared spectroscopy, gas-liquid chromatography, and gel electrophoresis.
- CHM 206 Organic Chemistry II: This is a continuation of a two-course sequence, focusing on synthesis and techniques relating to isolation and purification of organic compounds.

Georgia Institute of Technology

Georgia Tech/Emory Center for the Engineering of Living Tissue (GTEC)

GTEC's educational mission is to educate students and professionals in the engineering of living tissues and bioengineering/bioscience. GTEC is committed to the concept that research in a university is inseparable from education, particularly the important integration of engineering, biology, and information technology. New challenges require new approaches to research. GTEC believes it is the responsibility of the research university to be concerned with integrating research and education as early as the pre-college stage and continuing throughout an individual's professional life. Its goal is to change the culture to produce a new generation of engineers with a cross-disciplinary team perspective. These cross-disciplinary teams include students and teachers from K-12, undergraduates, graduate students, faculty, postdoctoral fellows and research scientists, and industrial professionals.

K-12 Outreach: GTEC sponsors many interactions with area middle and high schools for the dissemination of information regarding the idea of merging biology with engineering. Some of these initiatives are listed below.

GTEC Student Council visits area middle and high schools to present Prosthetic Pete, an interactive display with mechanical devices for replacements and improvements in the body plus descriptions of tissue-engineered replacements being developed. This initiative enables K-12 students to learn about the possibilities available to them in college curricula and enables K-12 teachers opportunities to enhance their classroom teaching. The key contact for scheduling Prosthetic Pete in classrooms is Eric Vanderploeg at gte217r@prism.gatech.edu.

GTEC has received a National Science Foundation Research Experience for Teachers (RET) award that will enable K-12 classroom teachers the opportunity to experience research in the GTEC labs for eight to 10 weeks each summer. This grant provides resources for the hosting/ mentoring laboratory and for the teacher to purchase equipment for his/her classroom. GTEC has a standing collaboration with the Georgia Industrial Fellowships for Teachers (GIFT) program within the Georgia Tech Center for Education Integrating Science, Mathematics and Computing (CEISMC). The teachers participating in RET are linked to the CEISMC GIFT program, thus enabling interactions with their peers involved in other laboratories and providing support for development of classroom strategies for enhancing student learning when they return to their schools. The key contact is Sally Gerrish at sally.gerrish@ibb.gatech.edu.

Career Academy in Health Technology, Henry W. Grady High School, Atlanta, GA, is a health technology emphasis program at an inner-city public high school and is supported by GTEC with lab tours/demonstrations and a shadowing program for juniors and seniors.

SciTrek, Georgia's Science and Technology Museum, with the help of GTEC and other universities and companies within the Atlanta area, has developed a high school program, BioTrek, to provide in-depth learning of technical and scientific biotechnology concepts. BioTrek is a three-year project for hands-on exposure to biotechnology topics for area high school students and teachers.

GTEC's Web site provides a list of links[12] to existing interactive Web modules for use in K-12 classrooms.

Undergraduate Outreach: In an effort to provide hands-on laboratory experience for undergraduates from throughout the country, GTEC sponsors two internship programs. These programs target students majoring in engineering or the sciences with an interest in bioengineering and/or bioscience.

> **Research Experience for Undergraduates (REU)** is a program for juniors and seniors with an interest in bioengineering and bioscience. The program is recruited nationally for a 10-week paid internship with housing and travel subsidy provided.
>
> The internship includes work on laboratory research projects proposed by graduate student mentors, a series of communication training seminars, seminars dealing with ethical issues in biotechnology, research seminars, and visits to Atlanta area bioengineering industrial sites.
>
> **Undergraduate Research Scholars (URS)** is a program for rising juniors and seniors with at least a 3.3/4.0 grade point average and a demonstrated interest in bioengineering and bioscience. This program is recruited at Georgia Tech, Emory University, and other metro Atlanta colleges and universities. It is a full-year commitment with a semester of credit and two semesters of stipend. The internships include laboratory research on projects proposed by graduate student mentors with stated goals and timelines for success, participation in seminar series presentations and poster presentations at GTEC events, communication training, and industrial field trips. Scholars have the potential for inclusion on publications based on their year-long projects.

Graduate Programs:

> **Management Minor:** In order to prepare graduate students for careers in industry, a minor has been established in cooperation with the Georgia Tech DuPree College of Management. This 12-credit-hour minor may be used to satisfy the Georgia Tech institute-wide minor requirement for Ph.D. candidates. The curriculum is designed to provide study opportunities in management and entrepreneurial issues affecting biomedical technology. The minor includes three core courses: Principles of Management, Legal Issues in Engineering Entrepreneurship, and Technology Ventures. Additional elective coursework options include New Venture Creation, Marketing Management, Manufacturing Strategy, and Forecasting and Analysis of Emerging Technologies.
>
> **Mentoring:** GTEC considers the mentoring aspect of its education program very important. GTEC offers seminars throughout the year on topics of mentoring—what it means to be a mentor, ideas on how to mentor and the benefits for all, and project planning and time management.

[12] http://www.gtec.gatech.edu/education/K12links.html.

These seminars are planned and presented by graduate students and the education staff. Graduate and undergraduate students in IBB and GTEC and interested faculty are encouraged to participate in the discussion seminars in preparation for the opportunities they have to work together in the laboratories through the REU and the URS programs. The key contact is Sally Gerrish (sally.gerrish@ibb.gatech.edu) for further information.

Industrial Internship Program: GTEC's goal is to offer selected graduate students the opportunity to perform research at a bioengineering company. Typically, a student will work on a project related to his/her Ph.D. thesis for a period of 10 to 12 weeks under the supervision of a senior researcher or engineer at the company and in conjunction with his/her academic advisor. The placement of students is based upon mutual agreement between the company, the student, and the academic advisor. Initiated several years ago, 25 Georgia Tech students have interned in industry over the past few summers. The key contact is Sally Gerrish at sally.gerrish@ibb.gatech.edu.

GTEC Student Council: Students involved in GTEC research are encouraged to participate in the GTEC Student Council.[13] This group of graduate and undergraduate students is organized into three committees: Education Outreach, Research, and Industry. This group was honored as one of two finalists for the 2000 Georgia Technology Leadership Award for Public Service. This award is given by the Governor of Georgia to recognize efforts to educate the public on technology advances.

Kennesaw State University

Bachelor of Science Degree in Biotechnology

The program of study in biotechnology leads to a bachelor of science degree and is designed to meet a growing national, regional, and state need in the area of biotechnology. This program consists of four tracks, each with track-specific requirements superimposed on a set of requirements common to all four tracks. The common requirements are designed to provide graduates with a solid, conceptual foundation as well as practical laboratory skills. Students have the opportunity to pursue a track in

- General Biotechnology
- Cytogenetics
- Molecular Diagnostics
- Forensic Molecular Biology.

Each of the four tracks is designed to fit a specific market niche within the overall field of biotechnology. However, completion of any of the tracks also will result in the graduate having sufficient conceptual knowledge to pursue advanced graduate or professional degrees.

Department of Technical and Adult Education (DTAE)

Quick Start Program

The Quick Start Program is a workforce training initiative of DTAE. The program was created as an economic development initiative to help industries start up and expand their operations in Georgia. In

[13] http://www.gtec.gatech.edu/gtecstudents/index.html.

many respects, Quick Start functions in a similar fashion to the ICAPP Advantage program, except the focus is on technical colleges.

Quick Start collaborates with companies to identify the best methods to train workers according to a company's needs. Quick Start promotes new business and industry expanansion by fostering economic development projects that center on workforce development.

The training services are customized to specific needs of the company. Part of the customization requires that Quick Start work with the local technical college to develop a curriculum for the client company. Once the training course has been designed, workers receive their training on-site or at the college. Quick Start offers these services and training programs at zero cost to the client. These partnerships sometimes can lead to further customized training courses at the technical college above and beyond the initial training services offered.

In the past the program worked primarily with traditional manufacturing-oriented companies. Quick Start has now begun a process of restructuring its services to be more applicable to the bioscience industry. Training service will essentially remain the same, but the program will tailor training technologies that are more in line with the needs of bioscience companies.

Key Contact: Mike Grundmann, Director of Marketing and Program Improvement, Georgia Quick Start, 1800 Century Place, Suite 300, Atlanta, Georgia 30345, Phone: (404) 679-2922, mgrundmann@georgiaquickstart.org

Size of Program: In 2002, Quick Start funded 315 training projects. New projects accounted for 134 of total projects, and expanding projects accounted for 181 of total projects.

Also in 2002 the program created 7,718 direct new jobs and facilitated an additional 18,523 indirect jobs for a total of 26,241 new jobs. The number of trainees for new, expanding, and existing companies increased by 2,385 (6.1 percent), from 39,416 in FY 01 to 41,801. This is a duplicated training count. Due to the complexity of today's jobs, most employees require training in multiple skill tracks. This year's number of trainees set another record for Quick Start.

Total economic development programs at Georgia's technical colleges served 1,410 companies, compared with 1,271 in FY 01. In FY 02, 1,142,348 hours and 6,485 courses of customized training were delivered through the Economic Development Programs divisions of the technical college system, serving 68,932 trainees.

Program Specifics: Typical services include training consultation, instructional design, implementation, training and evaluation. Appropriate training technologies are utilized and may include broadcast-quality video, training guides, job aids, trainer guides, transparencies, interactive video, animation, multimedia, and others as appropriate.

Training can be conducted for both pre-employment and post-employment programs. The only major requirement is that companies are able to create at least 15 new positions. On average, companies utilizing the program have produced 40 new positions.

Barriers to Success: Directors of the program feel confident that Quick Start possesses the fundamental tools to benefit the various bioscience segments. Program services are capable of being tailored to meet the needs of pharmaceutical, medical device, food processing, and chemical processing companies. Unfortunately, large-scale bioscience production in the state of Georgia is not at a level where Quick Start is readily used. However, program directors have taken proactive steps to ensure that the necessary pieces are in place for bioscience companies to take advantage of the Quick Start program.

MARYLAND

Maryland has a very active bioscience cluster development effort underway, dating back to the early 1990s when it was one of the first states to develop a comprehensive biotechnology development strategy. This strategic focus on the biosciences is found not only at the state level, but also within key regions of the state, notably Montgomery County, home of the National Institutes of Health, and Baltimore, home of Johns Hopkins University (JHU) and the University of Maryland Medical School.

Not surprisingly, given the long-standing focus on developing its biotechnology cluster, Maryland has an extensive range of workforce development activities in the biosciences. What is surprising is the degree to which these initiatives have arisen as separate, isolated activities that lack any strong coordination or overall state strategy.

Despite the growth of a robust bioscience base in Maryland, employing over 9,500 workers (not including hospital and medical lab sectors), the industry still employs mostly more educated workers. Of the 9,500 bioscience workers found in Maryland, only 458 are at the A.A. degree level, and 4,926 are at the bachelor's degree level.

OVERVIEW OF MARYLAND ACTIVITIES

Focus of Bioscience Workforce Development Programs

The specific bioscience sectors being targeted for workforce development include

- Research-oriented biotechnology companies and more academic/government lab workers
- Maturing biotech companies moving into biopharmaceutical manufacturing
- Medical technology workers for hospitals.

No strong medical device, pharmaceutical, or agricultural bioscience base is found in Maryland, and correspondingly not many workforce development activities in those areas.

Reflecting the base of Maryland companies and broad research activities, the training of students tends to fall into three main categories:

- General lab management and basic biotechnology lab techniques
- Bioscale-up/manufacturing activities
- Biotechnology management.

Range of Program Development Across K-20 and Extent of Articulation and Program Linkages

Maryland's bioscience workforce programs are quite broad, focus on a range of skill sets, and target student workers.

- At the high school career development level, four districts are developing biotechnology programs.

  An innovative program for high school graduates with some work experience is an entry-level biotechnician training program that places students with labs at Johns Hopkins University and select biotechnology companies in Baltimore.

- At the community college level, programs are focused on training students in general laboratory management skills relating to documentation and other good laboratory practices (GLP), together with basic biotech laboratory techniques for polymerase chain reaction, deoxyribonucleic acid (DNA) sequencing, etc.
- At the four-year undergraduate level, more focused biotechnology programs are beginning to supplement the traditional four-year biology program with more hands-on learning of molecular biology and genomics techniques, while still equipping students with strong basic biological knowledge needed for pursuing graduate studies. For instance, Towson State University has started a B.S. degree in molecular biology, biochemistry, and bioinformatics; Frostburg State University offers a biotechnology concentration for students pursuing a biology major.
- At the bachelor's level and graduate level, there are two specific program activities—a specialized program for bioscale-up under the chemical engineering program at the University of Maryland Baltimore County (UMBC) and a more general Biotechnology Techniques and Management at Johns Hopkins University.
- A significant professional development program also is found in Maryland for those already in the bioscience industry (along with significant numbers of attorneys serving industry) seeking more skills in core sciences, bioinformatics, regulatory affairs, and bioenterprise management.

Articulation and program linkages are developed on a case-by-case basis and not pursued at the system level. For instance, Montgomery Community College has strong articulation with Towson State and University of Maryland University College—both campuses of the University of Maryland System—but has failed to establish articulation with University of Maryland College Park or Baltimore County campuses.

Student Recruitment

Maryland has found success in advancing its bioscience workforce programs with nontraditional students—those who have been in the workforce in nonbioscience jobs, those working in the biotech industry, and those who were biology graduates but need more specific skills. From a program offering perspective, this has meant the need to offer more evening classes.

What have not been successful are attempts to develop closely knit tech-prep programs linking secondary, two-year, and four-year schools. Even attempts to link secondary schools to community colleges have not been successful.

Use of Strategic Assessment of "Supply and Demand" for Particular Bioscience Occupations

No comprehensive statewide bioscience workforce supply and demand study is guiding the development of programs. Instead, more focused regional studies on bioscience workforce needs have been conducted by interested organizations such as the workforce skill studies by the Suburban Maryland High Tech Council in the early 1990s and a more recent bioscience workforce skill study for the Baltimore region commissioned by the Baltimore City Mayor's Office of Employment Policy.

The state's Department of Education Career Development Division has been working with a group of bioscience employers to define career pathways and associated skill needs for the bioscience workforce.

This effort includes identifying occupational trends, but is not based on any analysis beyond the occupational employment projections by the state's Department of Labor, Licensing, and Regulation.

Industry Involvement

There is no statewide approach to gaining industry involvement to guide bioscience workforce development across secondary and postsecondary institutions.

Industry involvement is found on a program-by-program basis and varies widely. Typically, each program develops specific relationships with select bioscience companies or research labs and then gains their input in guiding curriculum and their helping in teaching or placing of students.

Linkages to Broader Economic Development Efforts

No proactive ties are found between the bioscience workforce development programs and economic development activities. While many programs use economic development as a justification for state investments in facilities or equipment, their day-to-day activities tend to be very separate from the state and regional bioscience economic development activities.

For instance, when the state developed its Bioprocessing Center in the early 1990s, there was an ongoing investment in developing a bioscale-up program in chemical engineering at nearby UMBC. However, no major attempt was ever made to link the two activities. In fact, they have each turned out to be very successful and very much separate.

Development of Curriculum

At the community college level and above, each program—even very similar ones—creates its own curriculum. There is no mechanism at the system level to share program development or learning.

One key factor noted for holding back the development of a common curriculum is a lack of industry standardization for bioscience positions.

At the vocational/technical/high school level, the State Department of Education is making a concerted effort to advance a common set of industry validated skill standards as part of the career education efforts. Working with industry representatives, the State Department of Education has developed three key pathways for bioscience career education in its health and bioscience career cluster—basic research, applied research, and manufacturing. The standards and pathways associated with these degree programs are not finalized and so are not publicly available at this time. What is interesting is that, despite the career cluster including health and the biosciences, there was no attempt to identify commonality between health and bioscience areas. The orientation of this career education program in the high schools is to stress the importance of four-year degrees given employer requirements. Curriculum development is left to the schools to interpret based on the statewide industry standards and further validation by local industry. For the future, the state is beginning to provide funding to promote schools to work in consortiums to develop curricula as part of career education efforts, but not consortium funding has been used for developing curricula for the biosciences.

Role of Experiential Learning Activities

Experiential learning tends to be incorporated via the curriculum and training on specific equipment rather than in formal capstone projects or internships with industry. The reasons appear to be the need for students to have a basic knowledge of GLP before they can effectively join a lab and for industry to be willing to hire students without prior work experience.

Teacher Training Activities

There is no formal process for training teachers. At the community college level, the biotech programs tend to hire Ph.D.'s who are expected to reach out to industry to fill in any gaps in their knowledge of regulatory requirements and lab practices.

At the high school level, budget cutbacks have resulted in training dollars being eliminated, which has hurt teacher training. The only sources for summer stipends to teachers is through federal labs, such as the National Institute of Standards and Technology (NIST) and the National Institutes of Health (NIH). The MdBioLab is an innovative pilot program using a mobile lab to train high school teachers as well as provide a hands-on exposure to the biosciences for students. Piloting this program in Frederick and Washington counties, two of the more rural areas of Maryland, has led to new upgrades in lab facilities and interest in starting a special biotechnology program.

Funding of Labs and Equipment

There is no separate line item for equipping and maintaining biotech labs. Rather, it is pursued on a school-by-school, program-by-program basis. Even the most widely heralded programs have had to be aggressive in seeking industry hand-me-downs to equip their facilities.

Key Success Factors

Clearly, a key success factor in Maryland is the growing demand for trained bioscience laboratory workers.

Establishing strong relationships with individual companies and research labs seems essential, particularly below the four-year degree level.

Specific leading programs include a highly successful post-high school training program for entry-level lab workers and a very well subscribed professional degree program offered by JHU that continues to evolve, adding a bioinformatics track, a regulatory affairs track, and a new M.S./M.B.A. program to build on its well-received bioenterprise track.

Barriers to Success

Lack of statewide coordination makes it difficult to replicate success—no mechanism recognizes success or advances it more broadly across the state. Programs tend to be smaller in scale and isolated in their activities.

Moreover, the absence of a statewide coordinated effort has resulted in gaps in program offerings due to a lack of resources. For instance, Frederick County Community College should be offering biomanufacturing, but is unable to because it lacks funding to add faculty and acquire the needed lab facilities.

Leading Program Activities in Maryland

Montgomery College Biotechnology Program

The Montgomery College Biotechnology Program offers students the ability to earn an associate's degree or a certificate in biotechnology. The program is well positioned today, but underwent a major realignment early in its development. When the program originally started in the late 1990s, it was targeted to high school students who were seeking more immediate career opportunities in the biosciences. Enrollment was quite low—well under 10 students—and the program quickly had to be refocused toward incumbent bioscience workers looking to upgrade skills and others with undergraduate degrees in the biosciences seeking more specific hands-on skills to enter the bioscience workforce. This refocusing resulted in the program offering evening courses.

Key Contact: Collins Jones, Ph.D., cjones@mc.cc.md.us, (301) 353-1910

Size of Program: The Montgomery College program has approximately 80 to 120 students per semester, with 30 to 40 graduates.

Focus of Program: The program is focused on skills development for research technicians and biomanufacturing.

Types of Students: Approximately 30 to 40 percent of the students are already employed in bioscience firms and are seeking to upgrade their skills. Roughly 50 percent already have their undergraduate degrees in the biosciences and are seeking more hands-on skill development.

Faculty: The Program Director, who, until this past year, was the only full-time faculty member, was a research scientist at NIH for 10 years and has strong skills in laboratory management. The program recently hired another faculty member, who has a Ph.D. and a strong background in academia. Extensive use is made of adjuncts from NIH, industry, and academia to teach courses. This is facilitated by offering most courses in the evening.

Curriculum: The development of the curriculum was done in close consultation with industry scientists through the outreach efforts of the Program Director. This outreach was more of an informal one-on-one process rather than a formal industry advisory process. This type of outreach continues to be the main way of keeping the curriculum current. Also, there is flexibility to customize based on specific hiring needs of firms.

Key customized courses in biotechnology include

- Cell culture and cell function
- Protein biotechnology
- Basic immunology and immunological methods
- Instrumentation for the biotechnology laboratory
- Nucleic acid methods.

Through these courses, the students learn not only specific techniques but good laboratory and good manufacturing practices. In addition, basic courses in biology, microbiology, genetics, and organic chemistry are required.

Facilities: Dedicated facilities were constructed for the basic instructional laboratories through state support. There is a major effort to keep equipment current. Very little funding is available through the college. The program relies on industry donations, including a recent $500,000 donation of used equipment by Life Technologies.

Experiential Learning: Because companies are resistant to having students as interns, the program eliminated an internship requirement that had been part of its design. It seeks to run laboratories with the same rigor and standard operating procedures found in industry to give students real-world experience.

Industry Partnerships: These are done as a one-by-one process rather than as a consortium effort. Key champions are BioReliance and Human Genome. Active placement of students exists, but again it is done one at a time. Over the past four years, 120 students have been placed into jobs.

Articulation: The Program Director commented that articulation was “a beast” and has had only mixed success. It is generally done better with second-tier four-year schools with specialized programs in biotechnology. The flagship programs in Maryland have been resistant to accepting the associate degree as a program articulation into their four-year degree programs. There is limited articulation with high school programs.

Special Programs: A short-term continuing education program has been tried, but it has not taken off because most companies offer this in-house and Human Resources/Training is often threatened and unwilling to try new approaches.

Keys to Success:

- Active role of Program Director in outreach to industry and meeting the quality requirements of industry for workforce development.
- Recognizing potential of student body interested in pursuing biotech lab and biomanufacturing careers.

Barriers to Overcome:

- Resistance of companies to hire students with two-year degrees. Largely driven by human resource perspective.
- Lack of ongoing support for equipment and program development.
- Lack of scholarship funding and marketing resources.
- Inadequately preparation of high school students.

University of Maryland Baltimore County
Department of Chemical and Biochemical Engineering

The focus of this UMBC department is on biochemical, biomedical, and bioprocess engineering and covers a wide range of areas including fermentation, cell culture, downstream processing, drug delivery, protein engineering, and protein stability.

Size of Program: It has 120 undergraduates, of which 30 to 40 percent are community college transfer students and approximately 30 Ph.D. students.

Faculty: The entire department of chemical engineering is biochemical oriented. Currently, it has seven faculty members and expects to hire three additional faculty members. There is limited use of adjuncts to teach more traditional chemical engineering courses.

Curriculum:

- Because all of the faculty are biochemical oriented, the entire chemical engineering curriculum is infused with bioprocessing examples across even traditional chemical engineering courses.
- Unique specialized courses are offered for upper-level undergraduates and graduate students in biochemical engineering focusing on processing, bioenzymes, kinetics, etc., as well as in

regulatory engineering interface of biotech (good manufacturing practices [GMP], quality control, validation, etc.).

- In the undergraduate chemical engineering program, a bioprocessing track was established with requirements for biology and cell and molecular biology as part of the basic chemical engineering core.
- Undergraduate students are strongly encouraged to research biochemical issues with faculty. In doing so, students learn how to operate equipment, undertake key analytical procedures, etc.
- Graduate-level programs specialize in biotechnology with emphasis in bioprocess engineering, biomedical engineering, tissue engineering, recombinant organism processing, tissue culture processing, immobilization and separation technologies, bioremediation, bioimaging, and drug delivery.

Special Programs:

- The graduate certification program in biochemical regulatory engineering guides students through the process and explores pre-production considerations that can help ensure product approval. Basically, it covers from A to Z how to bring a product to market. The program was designed by industry and has been a key for working with industry. It is taught in teams with industry professionals.
  - Since its formation in the early 1990s, the program has served thousands—approximately 120 students per year.
  - It is linked via satellite feeds to other locations across the state. It is working with Sweden to offer courses via satellite feed and tapes.

Facilities:

- Initially, the department had to be very entrepreneurial to fit out laboratories and gain access to key equipment. By offering facility-conducted training workshops for industry, it was able to receive donations from equipment companies.
- Today, state funding has developed 7,000 square feet of state-of-the-art research laboratories, including fermentation, protein engineering, tissue engineering, adsorptive separations, bioreactors, pilot plants, purification, bioseparations, bio-optics and biosensors. Another 6,000 square feet of wet-lab space in UMBC Technology Research Center are used as incubation space.

Industry Partnerships: To maintain its active internship program with industry, the Chemical Engineering Department has an office specifically to establish internships and co-ops. Typically, industry turns to faculty—whom they use as expert consultants—to bring in interns and hire prospective employees.

Keys to Success: The focus of chemical engineering is solely on biochemical engineering, not on turf fights, but on infusing the curriculum with biochemical examples and building strong industry relationships. Entrepreneurial outreach efforts are made to industry to provide regulatory training, gain access to equipment, and generate internships.

Maryland: BioTechnical Institute of Maryland, Inc. (BTI)

This institute was formed through the efforts of a JHU cancer researcher, Dr. Margaret Penno, who began to train motivated young working adults with high school degrees and minimal, if any, college experience seeking careers in bioscience research lab support for her own laboratory. When approached in 1998 by an established Baltimore contract manufacturing company, Chesapeake Biological Laboratories, for more than a dozen laboratory technicians, BTI was formed.

The focus of BTI is on helping young working adults "gain skills to pay the bills." It emphasizes a very condensed program that leads to entry-level positions. Many students go on to continuing education programs. The BioTechnical Institute is a free-standing organization addressing the growing need for qualified and specially trained lab technicians in Maryland's rapidly expanding biotechnology industry. It does so with a variety of programs designed to increase the state's pool of credentialed bioscience and pharmaceutical technicians. BTI currently receives support from foundations, including Abell Foundation—a local Baltimore community foundation—and the local chapter of the Open Society Institute.

Size: Since its formation in 1998, BTI has placed 105 graduates. Currently, approximately 50 to 60 students are trained per year in its laboratory technician program.

Faculty: BTI uses a combination of in-house and industry experts to provide training. The two Ph.D. in-house training staff focus on basic scientific training, such as cell cultures, while industry experts offer training in areas reflecting industry practices.

Program/Curriculum: The laboratory technician program involves a 12-week program geared for working adults with high school degrees and minimal, if any, college courses. The first nine weeks are in-class training, and the last three weeks are on-site internships with participating organizations. Currently, the program is running at a 65 percent completion rate and an 80 percent placement rate.

The curriculum is designed in coordination with bioscience firms. The focus is on entry-level workers in a research laboratory environment. It is not sufficient to meet the requirements for clinical lab certifications. Basic elements of the curriculum include clean room practices, techniques in cell culture, GMP, laboratory safety and GLP, cleaning and sterilization, gowning techniques, weights and measurements, laboratory math, introduction to animal care, and techniques in molecular biology. Extensive use of lab work reinforces basic education.

Facilities: BTI is located in a bioscience incubator located at Baltimore City Community College in downtown Baltimore.

Special Programs/Features:

- Pre-screening—A focused effort is made to ensure that students with aptitude and motivation are part of program. Of those who inquire about program, only 12 to 14 percent are accepted. This multiphase process involves initial screening for basic aptitude to more intensive academic and personal interviews. Nearly all students have a proven employment record, though typically in dead-end jobs. Referrals for students come from a variety of sources including community-based organizations, workforce development entities, and self-referral based on earned media stories.
- Employment Support—BTI recognizes that its students may be held back by a variety of problems stemming from low self-esteem, fear of education, and home-based problems. Time is taken in the program to work closely with students on these issues as required.

- Professional Training—An emerging focus of BTI also is to provide professional training to existing laboratory technicians working in industry. It seeks to offer both pre-set workshops and more employer-customized workshops. The focus is on the basics of cell culture techniques. This training is seen as a way to generate revenues as well as increase linkages with employers.
- Training and Accreditation Programs—These are free of charge to participants who qualify based on high school (or general equivalency diploma) record and aptitude assessments. The BioTechnical Institute, organized as a not-for-profit corporation, is supported by the Abell Foundation, MdBio, Maryland state and local agencies, and the bioscience community.

Industry Linkages: BTI works actively with 25 firms and organizations, which are sources for internships and job placements. Leading groups include Johns Hopkins University and Chesapeake Biological Laboratories.

Keys to Success:

- Identify a specific niche—research laboratory technician
- Enlist key champion and community foundation support
- Ensure quality—both through pre-screening and program—while aware of social dimensions of effort.

Master of Science in Biotechnology at The Johns Hopkins University

Starting 10 years ago, the Johns Hopkins University began offering a master of science in biotechnology as a part-time graduate program. It is a heavily science-based program that has evolved over the years to meet the continuing evolution of the industry and career challenges of its students.

Size: More than 500 students engage in coursework each semester. The typical student is a current bioscience worker with a bachelor's degree in his/her late 20s or early 30s. Another significant source of students are attorneys working with bioscience industry.

Faculty: The program primarily uses adjunct teachers drawn from industry.

Curriculum/Special Program Features: The program offers a wide-ranging curriculum involving 34 course offerings across core sciences, bioinformatics, regulatory affairs, and bioenterprise management. It requires 10 courses to complete the master's degree. Completing the degree typically takes two years on a part-time basis, with four core courses involving biochemistry and advanced cell biology. Students have the opportunity to concentrate in particular career tracks including bioinformatics, regulatory affairs, and biotechnology enterprise. This focus on career track was added as the program responded to student interest and needs, though many students decide to pick and choose electives across these areas of concentration.

The Program Director sees regulatory affairs emerging as a major area where growth in the program is reflecting the maturing industry in Maryland.

The bioenterprise management focus also has been augmented with a new combined M.S./M.B.A. program that can be completed in three years.

A certificate in biotechnology enterprise is available for those desiring a deeper understanding of the business aspects of biotechnology without completing an entire master's degree program—the certificate requires six courses. Students desiring to continue in the program can count four courses toward the 10 required for the master's degree in biotechnology.

Facilities: Because students are typically working at the bench level in their jobs, lab courses are electives, which reduces the need for extensive lab facilities. Both the master's degree and certificate programs are offered at the Homewood Campus of the Johns Hopkins University.

Industry Linkages: There is no internship or other experiential learning component because this is a part-time program for working professionals, many of whom already are working in bioscience companies. However, the program is strongly linked with the bioscience industry through its adjunct faculty.

Keys to Success:

- Strong growth of bioscience workforce seeking to gain more advanced degrees.
- Highly customer focused and able to evolve program to meet student and industry needs.
- Ability to draw on adjunct faculty from across the community.

OREGON

Bioscience workforce development and training initiatives in the state of Oregon have been limited and unmethodical. Several Oregon institutions have indicated that the bioscience industry in Oregon is still in its development stages. The fact that the state lacks a critical mass of bioscience industry activity is the major reason the state lacks a comprehensive program addressing bioscience workforce needs.

According to the August 2001 Oregon Health and Science University newsletter “Outlook,” the state’s bioscience industry experienced marginal growth in the course of recent history. The Oregon Bioscience Association found that the state’s employment numbered approximately 3,000 across 100 different companies in 2001. Conversations with educational and industry leaders indicated that, until recently, Oregon’s primary economic development activities have centered on the information technology (IT) industry. With the bioscience industry still in its early stages of development, the demand for bioscience labor has remained low. The result has been sporadic workforce development activities.

Workforce training and development programs that have been implemented are concentrated primarily in the Portland metropolitan area where bioscience activity is most pronounced. These existing workforce development initiatives are wisely focusing on building off of new and current industry development strategies as well as centering on connections with new and emerging academic research activities at the Oregon Health and Science University.

OVERVIEW OF OREGON ACTIVITIES

Focus of Bioscience Workforce Development Programs

The state has yet to concretely establish a specific niche for the bioscience industry. Industry and academic leaders are investigating ways to link the existing strengths of Oregon’s IT industry and translate it into the bioscience industry. Currently, Oregon possesses a number of medical device manufacturers that produce equipment possessing large amounts of sophisticated electronic and silicon base high-tech parts. The strength of these two market niches has led the state to identify Multiscale Materials and Devices as one of its Signature Research Centers. Plans are in place to establish three more centers.

The universities in Oregon are in a unique situation. Absent a critical mass of industry activity, the state universities are positioned as the major leaders in bioscience development in the state of Oregon. As the universities increase their capacity for biomedical research, the programs at each university are essentially training students to become cutting-edge research scientists who are in line with the research objectives of the schools. In many respects, Oregon universities currently are shaping the demands for bioscience employment.

Unfortunately, there is no comprehensive plan in Oregon specifically addressing the labor needs of the bioscience industry because the state has yet to determine the emphasis of its overall economic development strategy. To date, programs have been created primarily based upon the ability of an institution to identify local bioscience-related workforce needs. However, due to the lack of a significant industry presence and unspecified state economic development initiatives, several programs have chosen to concentrate on K-12 education as well as increasing the population of students seeking higher education degrees.

Range of Program Development and Linkages

Bioscience workforce programs in the state of Oregon are, for the most part, wide ranging in nature across the educational spectrum. Workforce activities stretch from K-12 to community colleges to higher education. However, the level of interaction and coordination among the existing programs is moderate.

- The greatest degree of program interaction occurs between K-12 and higher educational institutions. These outreach programs address both student and teacher development at the K-12 level. These types of programs are geared toward cultivating and encouraging the younger student's interest in the biosciences. Simultaneously, teachers at the primary and secondary level are shown how to integrate biotechnology concepts into the classrooms and implement ways to continue to develop the interest of students.
- At the community college level, programs are designed to prepare students for positions in bioscience research. Students have the option of pursuing careers upon completion of the programs or transferring to a university for further educational development. Both tracks require a certain level of coordination with the Oregon University System. To a lesser degree, informal linkages exist with K-12 institutions for the purpose of promoting bioscience careers to younger students.
- The educational programs at the university level are numerous but lack cohesiveness and concentration. Each of the states' universities possesses bioscience-related programs and research yet do not emphasize a specific area industry activity.

Student Recruitment

Thus far, students have been enticed to pursue bioscience-related positions because of the industry's cutting-edge potential in Oregon. However, managers of existing workforce programs admit that the current labor market for bioscience workers in Oregon is very tight. This has kept down the price for bioscience workers, making it difficult to encourage the career path. The state of Oregon has a need for economic development officials to create a plan to boost demand for bioscience workers before the scale and scope of programs can be augmented.

Strategic State Assessment

The state has yet to identify any suitable niches within the bioscience industry to emphasize. Some programs have individually sought the feedback of industry in efforts to ascertain the needs of the industry. Unfortunately, without an obvious industry segment of the biosciences to target, it is difficult for educators to pinpoint specifically which skill sets are most crucial for the bioscience industry as a whole. Each subsector of the bioscience industry stresses a different set of skills critical for laborers.

Linkage to Economic Development Strategy

In December of 2002, the Oregon Council for Knowledge and Economic Development (OCKED) presented its strategy to enhance the state's economic position. OCKED identified three critical areas for the state: research and technology transfer, capital and business formation, and knowledge and workforce development. Several studies are currently being commissioned to ascertain the specific niches within the state's industry cluster that should be targeted for development.

The OCKED plan has identified three actions as it relates to workforce development in a broad sense. Action one targets the state's incumbent workforce. Initially, the council desires to identify those industries with high demand for knowledge workers, articulate the skill needs for those positions, and provide the incumbent workforce the training necessary to make the transition. Action two addresses ways to increase the capacity and effectiveness of higher education to graduate people with degrees in technology, engineering, science, and business programs. Action three seeks to increase the capabilities of K-12 institutions to encourage and prepare students to enter fields of science.

Industry Involvement

Industry involvement in Oregon bioscience workforce programs is limited. The nature of industry involvement in bioscience workforce initiatives that does exist in Oregon is, for the most part, informal. The result has been that programs are broad in scope. Programs do not necessarily emphasize the specific skill set requirements of any particular industry segment. Rather, the focus is on exposing students to the general understandings required for positions in the wide-ranging bioscience field. Program managers and directors hope that, as the state moves forward in developing a comprehensive plan for the bioscience industry, specific industry segments will be identified allowing institutions to target potential business partners to cultivate relationships.

Development of Curriculum

Since there is no statewide strategy for bioscience workforce education or training, each individual program has used different means to create its curriculum. Some institutions have implemented programs that model nationally accepted skill standards. Other programs have attempted to tailor curriculum to meet the specific needs of the Oregon bioscience community. These methods reflect different goals. Programs that strive to place graduates directly into careers upon completion must implement a curriculum fitted more closely to industry needs. Programs that emphasize basic understanding of the bioscience field are designed for those students intending to transfer to other institutions for higher education degrees.

Role of Experiential Learning

Programs that aim to place students directly into positions in the industry find it challenging to provide students with experiential learning opportunities. Several firms in Oregon are in development stages and tend to be smaller in nature. These characteristics make it complicated for programs to develop the scale of industrial interaction that is beneficial for students. Programs also find it difficult to place students due to the high-level skill requirements that companies and institutions demand of prospective students.

Teacher Training Activities

Training of teachers is very prevalent in Oregon; however, these initiatives are informal and take place primarily at the K-12 level. The emphasis on K-12 professional development partially stems from federal government funding directives. Outreach programs exist between K-12 institutions and universities, as well as with community colleges. The objective of the relationships is to demonstrate to teachers how to incorporate bioscience curriculum into the classroom. Some initiatives are highly structured, while others occur in a more unceremonious fashion.

Facility Funding

Institutions that have enacted bioscience programs have had to be creative in finding sources of funding. Absent a coordinated, comprehensive state strategy for the biosciences, the funding of programs has been arranged through different means. Some programs have been able to obtain state and federal support on a program-by-program basis. Other institutions have been able to support programs through issuing bonds or through general revenue sources. Overall, there is no singular source for facility or program funding.

Key Success Factors

Key factors of success have been connecting students to Oregon research universities, whether as employees working in the various research labs or as students pursuing advanced degrees in bioscience research. Program directors understand that presently the greatest opportunity available to individuals seeking a career path in the biosciences is at the state's universities. Establishing ties between students and universities has been tantamount to success.

Barriers to Success

The absence of a cohesive statewide plan targeting bioscience workforce issues has been one of the biggest obstacles to success. First and foremost, the state has not adopted any kind of economic development policy for the bioscience industry. This has made it difficult for educational leaders and workforce training managers to tailor programs to meet the skill set requirements of specific bioscience niches. Second, the state is faced with budgetary constraints. Developing programs in such harsh economic times is an extremely difficult task.

The absence of a critical mass of industry activity is another major barrier the workforce training and educational programs must face in Oregon. It is extremely difficult to cultivate meaningful workforce programs without industry interaction. Existing and emerging training programs do not have a mechanism to design curriculum, sponsor experiential learning opportunities, or assess the adequacy of programs to train students entering the labor market.

Leading Oregon Program Activities

Portland Community College

Biotechnology Laboratory Technician Program

Portland Community College's Biotechnology Technician Program is the only major initiative in the state specifically directed toward training individuals to enter the labor market upon completion of the program. The emphasis of the program is on educating students about the techniques of laboratory technicians. The alternative used in the past was for employers to train technicians a bit at a time utilizing experienced workers to teach them. It was inefficient, expensive, and haphazard, as the things learned depended on what specific tools were in use in that lab at that time. Employers often don't have the time or money to train a person this way and thus look for more experienced workers, hoping that they will possess more of the necessary skills.

Graduates of Portland Community College's Biotech Lab Technician Program are trained to use the tools and techniques common to laboratory technicians. The biotechnician is a key player in any laboratory, absolutely critical to its smooth operation. Students are well prepared for entry-level (or better) positions in many different laboratory situations.

Key Contact: Kendra Cawley, Ph.D., Program Director, kcawley@pcc.edu, (503) 614-7282

Size of Program: Approximately 15 students enroll in the program annually. Some of the students in the program, about one-third, already have a bachelor's degree. These students enroll to obtain practical laboratory research skills that often higher educational institutions fail to provide. The program averages five to seven graduates per year.

Faculty: One full-time

Curriculum:

- An introduction to the biotechnology industry and related areas includes an overview of applications of biotechnology, industry activities, employment and career opportunities, and ethical legal and social issues. This course is not restricted to students in the biotechnology program.
- Laboratory Mathematics is designed to focus the student's mathematical skills on problems used on a daily basis in the biotechnology laboratory.
- A two-term course in which the first term covers general laboratory safety and hazardous chemicals use and disposal; and the second term covers biosafety procedures, use and disposal of biohazardous materials, and radiation safety.
- Basic Laboratory Techniques and Instruments course is designed to acquaint students in the biotechnology program with fundamental laboratory skills. The course supports the concepts of solution prep calculation and data analysis introduced in laboratory mathematics.
- Media Preparation covers the principles and practice in preparing media used to culture cells and microorganisms. Solutions prepared by students in this course are used to support activities in Tissue Culture and Molecular Biology.
- Techniques in Molecular Biology is a two-term course focusing on the theory and practice of techniques used in the analysis and manipulation of deoxyribonucleic acid. This course focuses on structure/function relationships of biological molecules.
- Applied Immunology familiarizes the student with the general properties of antibodies and a variety of immunological applications in research, diagnostics, and therapeutics.
- Tissue Culture is a two-term course that gives students training and significant practical experience in common cell culture techniques. Students maintain cultures of continuous cell lines throughout the course. These cells are used to demonstrate a variety of cell culture-related procedures and also may be used for applications in other courses.
- Students will be placed in biotechnology laboratories for a 10-week internship, a total of 240 hours of work experience.
- Regulatory Compliance introduces students to the various regulatory bodies with jurisdiction over activities in a variety of biotechnology laboratories.

Facilities: The Biotechnology Laboratory Technician Program works in several areas of laboratory research. The program works in the areas of molecular biology, tissue culture, and protein chemistry. These areas of focus require the program to maintain a laboratory outfitted with state-of-the-art equipment in order to carry out a broad range of typical laboratory procedures.

Major infrastructural enhancements at the school were covered by a bond measure that funded the building in which the biotech lab was built. The school also received some funding from the Regional Strategies Board—this organization was charged with distributing lottery money for the development of targeted key industries (biotech being one of them). And the college made a considerable capital investment. The equipment at the school is still appropriate to the training that takes place—upgrading equipment is not a pressing issue.

Industry Partnerships: When the Biotechnology Laboratory Technician Program was initially designed, industry was heavily involved. The program was created in 1994 stemming from regional initiatives to bolster the bioscience industry. Companies were asked for their input in identifying the most crucial skills needed to develop a program to train research laboratory technicians.

Other than the initial relationship with industry, very little interaction has taken place. The industry base in the Portland region is relatively small. Those companies that do exist tend to be 15-person firms. The Biotechnology Laboratory Technician Program does have a relationship with Oregon Health and Science University. Students are often placed in internship positions at the university. The majority of students also receive employment at the university after completing the program.

The Biotechnology Laboratory Technician Program also interacts with K-12 institutions, but on an ad-hoc basis. The relationships tend to be geared toward field trips. The Program Director gets involved with continuing education programs, providing teachers with new methods to incorporate new technologies and application of biotechnology science.

Keys to Success: Placing students into well-paying entry-level positions in research laboratory situations is the key measurement of success. However, this has become increasingly difficult. Oregon does not yet possess an adequate level of biotechnology industry activity. The main source of job placement to date has been the Oregon Health and Science University (OHSU), which is still in the process of establishing itself as a top-tier bioscience research institution.

Positions at the university tend to be on the lower end of the pay scale for research laboratory technicians. Placement at the OHSU is complicated by the stringent university policy of hiring only individuals with bachelor's degrees as salaried staff. Internships are the only way to prove that associated degree people are adequately trained to fill the research associate positions. With the challenge of facing a tight labor market upon completing the program, prospective students often steer away from it. The program's rigorous curriculum and intensive lab requirements add to the disincentive.

Barriers to Success: The economic downturn and the budget issues facing the state have made it difficult for the program to succeed. Portland Community College was forced to reduce its budget by $10 million. The Biotechnology Laboratory Technician Program is one of the programs that the school has decided to suspend. The lack of a robust bioscience industry to employ students, dwindling student interest, and reduced funding availability have contributed to the program's suspension for three years.

Mount Hood Community College

Associate in Arts of Oregon Transfer Degree in Biology, with Biotechnology Concentration

The Mount Hood Community College program is in its initial stages of development. The school is in the process of investing and developing a strategy emphasizing the biosciences. Currently, Mount Hood offers an Associate in Arts of Oregon Transfer Degree in biology, allowing a student to complete all of his/her freshman and sophomore general education requirements for a bachelor's degree at one of the Oregon University System institutions.

As part of an ongoing effort to emphasize the opportunities in the bioscience industry, the school strives to integrate bioscience concepts in its current biology program. Specifically, Mount Hood Community College offers a course that demonstrates to students several of the key concepts in biotechnology. The course provides students the opportunity to draw on disciplines in chemistry, engineering, and physics. Students are shown how these fields are connected and applied to computer technology, manufacturing, and laboratory research.

The school is focusing on a strategy to further develop the bioscience emphasis, specifically geared toward phase III drug and pharmaceutical biomanufacturing. Mount Hood Community College has taken proactive steps toward this endeavor in the form of investments in new facilities and equipment upgrades.

Key Contact: Beth Pitonzo, Ph.D., Associate VP of Instruction, Dean of Science, (503) 491-7137, pitonzob@mhcc.edu

Size of Program: Currently, the biology program has anywhere from 75 to 100 students. Typically, 16 students make the decision to focus their studies specifically on bioscience-related topics.

Curriculum: As the school moves forward to concentrate on bioscience workforce training initiatives, faculty members understand that it is imperative to expose students to a set of skill standards that is widely accepted by industry and academic professionals. Faculty members have taken steps to develop a set of courses that takes into account the curriculum housed by Bio-Link, a National Science Foundation Advanced Technological Education Program.

The school also makes an effort to coordinate its initiatives with the needs of industry as well as institutions of higher education. Mount Hood Community College stands ready to work with bioscience employers to tailor specific work training programs for professional development. Though the school has yet to identify specific industry partners, the Mount Hood's president feels that the programs will act as major location incentives for companies. The school also coordinates its programs with universities to ensure that the curriculum is transferable.

Facilities: In June of 2003 Mount Hood Community College broke ground on a new $15.6 million Allied Health/Biotechnology building. The $15.6 million will be divided between the two programs, with $7.6 million being earmarked for biotechnology initiatives. The new 37,434-square-foot building will set aside 18,249 square feet specifically for biotechnology education.

The facility is being funded in part through a $68.4 million bond measure. Funds for equipment were covered in part by the Mount Hood Economic Alliance, which administers the Regional Investment and Rural Investment Board Programs. The Alliance allocated state lottery funds to pay for the equipment needs of the school's new facility.

Oregon State University

Professional Master's Degree in Applied Biotechnology

The objective of this degree is to train students to be able to function effectively in industrial environments. With this practical goal in mind, Oregon State University (OSU) has crafted the Professional Master's Degree Program in Applied Biotechnology to offer students and their corporate sponsors a maximum of flexibility in choosing from the university's extensive graduate curriculum in the biological sciences. The Professional M.S. Program in Applied Biotechnology has been shaped with the help of professionals employed in leadership roles in applied biotechnology industries and agencies. The Board of Professional Affiliates includes several collaborating partners for the Professional M.S. Degree Program in Applied Biotechnology. Industry internships, which place students in industry positions for three to six months prior to graduation, play an important role.

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Curriculum: The academic program for the Professional M.S. Program in Applied Biotechnology includes intensive laboratory experience courses, core lecture courses, and professional cohort courses, as well as an internship. Highly motivated students with strong academic backgrounds may be able to complete this Professional M.S. Program at OSU in one calendar year (based on full-time study for a minimum of 45 credit hours). However, most students are expected to take two years to complete their programs.

Intensive Laboratory Courses: Molecular Techniques (MCB 525) is a two-week summer course that has attracted students from around the country for eight years to learn molecular biology theory and practice. A new laboratory course entitled Advanced Bioscience Technologies (MCB 526) will be added to the curriculum. Topics will include optical methods (flow cytometry, fluorescence microscopy, and image analysis), an introduction to high-throughput technologies (e.g., robotics), and advanced molecular techniques and procedures (pulsed field gel electrophoresis and bacterial artificial chromosome vectors). Bioinformatics training also will be an option.

Core Lecture Courses: Traditional coursework provides the conceptual framework necessary to contribute in a biotechnology environment. Microbial genetics, structure and function of eukaryotic cells, eukaryotic molecular genetics, and cell signaling and development are some of the topics covered.

Internships: Students have an opportunity to gain practical experience through a three- to six-month internship with one of the program's collaborating partners. Maximum flexibility has been instilled in this component of the program to attract corporate partners. Students are required to draft a proposal for their intern experience during their first two quarters at OSU. A faculty mentor helps define specific objectives for the proposal, identify potential host agencies, and then formally initiate and coordinate the internship with an industry supervisor. A formal process is used to evaluate internship proposals from industry partners as well as student performance during and following internships.

Prior employment experience generally may NOT be substituted for internship experience. Individuals who are currently employed may elect to obtain internship experience within a different part of the same organization or in research laboratories at the university. An informal mid-internship evaluation facilitates successful completion of this experience, and a written report summarizing the internship experience is required of the intern.

Portland State University

Oregon Biotechnology Education Program (OBTEP)

The program provides teacher training workshops at both a Portland metropolitan site and at three rural satellites, during which teachers are trained in the principles and practices of biotechnology and gain experience with hands-on experimental biotechnology curriculum modules. During the school year, the program provides free equipment loans to teachers in the program for use in their classrooms. A Mentor Teacher program in which teachers who have been involved in the program for a significant number of years and who are familiar with the curricula plays an active role in providing follow-up support for new teachers in the program.

The first annual OBTEP Spring Symposium was held in the spring of 2001 at the Portland metropolitan site. The symposium provided an opportunity for teachers in the program to come together, see demonstrations of new curricula and products, hear a prominent guest lecture from an invited specialist in the field of biotechnology, and participate in a poster session highlighting the ways in which teachers have integrated the equipment and curricula into their classrooms.

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Size of the Program: In the 2000–2001 school year, the program had a total of 33 participants. The number of teachers and pre-service teachers participating in the program was 28.

Cooperating Agencies/School Districts: Portland metropolitan area: Portland Public Schools, Beaverton, Canby, Corbett, David Douglas, Forest Grove, Gresham, Hillsboro, Oregon City, Parkrose, Reynolds, Sandy, Sherwood, Tigard-Tualatin, and West Linn-Wilsonville.

Eastern Oregon satellite schools: Hermiston, Joseph, Ontario, La Grande, Pendleton, Milton Freewater, Pilot Rock, Stanfield, Cove, Imbler, Grant Union, Long Creek, Prairie City, Huntington, Ontario, Pine Eagle, Baker City, Adrian, and Nyssa.

Keys to Success:

- Increased number of teachers and pre-service teachers are trained in the biotechnology curricula and using the equipment in their classrooms.
- Increased number of Oregon high school students receive training in the growing field of biotechnology so that they are able to make sound judgments relating to the impact of biotechnology on their lives.

Program Funding: OSU manages the Oregon Eisenhower Professional Development Program funded by the U.S. Department of Education. The Eisenhower Professional Development Program provides financial support in the form of grants for (1) intensive professional development opportunities for elementary and secondary school teachers and (2) enhanced training for pre-service teachers, in support of Oregon's School Improvement Plan. OBTEP received $43,190 from the Eisenhower Professional Development program for FY 2000–2001.

TEXAS

For many years and particularly since the tech boom of the early 1990s, Texas has been a home for technology and technology-related companies spanning information technology to bio-technology to electronics and many other technology-related industries. Development of the technology industry in Texas has helped to insulate the state from the recent economic downturn and helped prosperity thrive in this southern state. While part of this development can be attributed to the spawning of new ideas combined with an entrepreneurial spirit, part also can be attributed to a regulatory environment that has adapted to the changing needs of the economy. In 1999, the Legislature approved omnibus tax relief legislation, which included provisions that will directly benefit the biotechnology industry in Texas. This legislation included a research and development (R&D) tax credit for qualified expenditures after January 1, 2000. For reports due before January 1, 2002, the R&D credit is limited to 25 percent of the corporation's franchise tax liability. For reports due on or after January 1, 2002, the R&D credit is limited to 50 percent of the corporation's franchise tax liability. Any unused credit may be carried forward for up to 20 consecutive reports. With more than $490 million spent in life science research in the Houston area alone, these tax credits will be a marked improvement for the biotechnology industry. Additionally, Texas has four centers of excellence with a combined budget of $8 million that assist the local biotechnology industry. The Advanced Research Program/Advanced Technology Programs, including a technology development and transfer program, allocate more than $16 million a year to biotechnology, biomedicine, and biological sciences. This funding is provided through the Texas Higher Education Coordinating Board. Texas has an open formulary with prior authorization required for certain drugs including growth hormones. Many Texas cities and counties have programs to encourage business development through economic incentives, incubators, and research parks, some geared specifically to the biomedical and biotechnology industry. The success that Texas has had in developing its biotechnology industry has largely been accomplished without a strong emphasis on bioscience workforce development.

OVERVIEW OF TEXAS ACTIVITIES

While it has not yet developed a full bioscience workforce strategy, Texas is beginning to recognize the importance that such an investment would yield in the state. In August 2001, the Career Development Resources (CDR) of the Texas Workforce Commission (under a grant from the Texas School-to-Careers Office) developed a report[14] that amounted to a white paper out-lining the impact that "new economy" industries might have on the economy of Texas. While the idea of workforce development was briefly mentioned, neither specific recommendations nor references to biotechnology were specifically addressed.

More recently, the CDR developed a report[15] in which a methodology was developed to identify target industries with the best possibility for employing emerging and evolving occupations. The

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[14] *Technology Workers in the New Texas Economy: How Technology-Driven Changes in the Workplace Are Reshaping Choices at All Levels from Community Development to Individual Career Decisions,* Career Development Resources, Texas Workforce Commission, August 22, 2001.

[15] *Biotechnology: Impact on Emerging Occupations,* Career Development Resources, Texas Workforce Commission.

report also listed the requisite knowledge, skills, and abilities; minimum education and training needed; wage estimates; and projected openings required in the bioscience industry for each respective occupation based on standard available secondary data sources, such as the Occupational Employment Statistics Sruvey.

With the growing realization of the importance of the bioscience industry in Texas, the Texas Workforce Commission sought to expand on the previous evaluation of the bioscience industry commissioned by the CDR. In so doing, it fleshed out a representation of trends in occupational employment in various industries that fall into the broad “biotechnology” category developed in the CDR’s report and composed Biotechnology Occupational Trends. The report looked at staffing patterns within those industries to determine which occupations were technology- or knowledge-intensive—recognizing that not all occupations in a “high tech” industry will be technology- or knowledge-intensive. The convergence of these two agencies, in which one builds off the former agency’s work to develop a cohesive voice in this quickly changing industry, is representative of the kind of coordination that will be necessary to effectively implement a workforce strategy in the biosciences.

Paralleling these efforts, in 2002 Rick Perry convened the Governor’s Council on Science and Biotechnology Development. The Council is striving to create a seamless system of innovation from the laboratory to the marketplace in the biotechnology industry. As a resource to the Council, the CDR is committed to continuously updating its forecasts on the workforce implications of biotechnology as researchers break new ground, entrepreneurs bring new products and services to the market, and the efforts of the Governor and the Council leverage public funds to accelerate the industry’s growth and development in Texas. To date, the activities of this Council have been limited. But, with a Governor who has a health care background, there are high hopes for the Council. With the continuing realization of the importance of the bio-sciences to the U.S. economy and particularly the economy of Texas, many efforts are underway to fill the Texas workforce with proficient bioscience workers who will successfully meet the demands of bioscience companies in the state. The major biotechnology association in Texas, the Texas Healthcare and Biosciences Institute, is currently seeking to develop a statewide, coordinated bioscience workforce strategy that will effectively tie the current workforce initiatives together. This initiative recognizes that success depends on a cohesive strategy, that simply having multiple college degrees and programs with high accolades in the state is not enough.

Range of Program Development Across K-20 and Extent of Articulation and Program Linkages

Texas’s bioscience workforce programs are quite varied from one program to the next and are contingent on the individual/committee that was the catalyst for program initiation.

Though varied, many of the community colleges promise similar skills sets upon completion of the program. These can range from basic skills in laboratory methods, molecular biology, and laboratory instrumentation to more advanced procedures in gel electrophoresis, recombinant deoxyribonucleic acid (DNA) techniques, cell culture techniques, polymerase chain reaction, bacterial culturing, bacterial transformation, restriction enzyme use, and bioethics. Some programs also recognize the importance of a successful career that involves more than just technical skills and stress creating a portfolio of accomplishments including verbal, written, and electronic media skills.

Articulation agreements and other program linkages do exist but on a program-by-program basis rather than at the state or regional level. Agreements exist between North Harris Montgomery Community College and the University of Houston that utilize a 2+2 program resulting in a bachelor's degree in biotechnology, with more agreements currently being developed.

Student Recruitment

Major attempts at student recruitment do not appear transparent at many of the programs in Texas. A one-of-a-kind program was developed at Austin Community College (ACC) that begins its public education/recruitment efforts as early as middle school to capture the students at the prime level of curiosity and career ambitions. Part of this recruiting effort includes educating parents on the value of a biotechnology career for their children, as well as starting biotechnology clubs in high school for the students themselves. Due to the success of this program, more students are coming from abroad from places such as India and China. Bioscience videos have been developed to educate students (with help from industry) to show that careers in biotechnology are not as stale as they might imagine (the appeal of attractive male and female workers in the video stresses this point). A four-year certificate in biotechnology is being developed at the high school level. Montgomery College in Houston is looking at the possibility of targeting Hispanics for these biotechnology programs. In doing so, it has looked at programs at Yaccamaw, Washington, and San Diego that have translated their curricula into Spanish. Many institutions, particularly at the community college level, offer tailored workforce training programs for people already in the workforce and have found some success with this program. Many of the students are coming into the programs from the existing workforce.

Use of Strategic Assessment of "Supply and Demand" for Particular Bioscience Occupations

An assessment of what occupations fit into the Texas bioscience economy and the current *supply* of bioscience workers has been conducted (and will be continually updated) by the Texas Workforce Commission and CDR, respectively; but, a true sense of the labor market *demand* for these workers (i.e., using labor market statistics) has not yet been addressed. Regionally, efforts have been made by programs to address the need for bioscience workers and the skills needed by the industry by directly contacting companies in the area, rather than by utilizing statistical data to assess this gap.

Industry Involvement

There is no statewide approach for industry involvement to guide bioscience workforce development. Industry involvement is found on a program-by-program basis and varies widely. In most cases, a program develops a rapport with specific bioscience companies for the purposes of internships/graduate placement based on successful placement in the past. Some programs use industry as a sounding board for curriculum development or teaching efforts and as a source of equipment for the biotechnology programs at the institutions. Austin Community College, in particular, uses industry to supply its equipment as well as to develop its curriculum. Industry professionals also have joined the teaching staff at ACC.

Linkages to Broader Economic Development Efforts

Linkages to economic development at the state/regional level are loosely tied, at best, to local workforce development efforts. While some of the regional efforts recognize the importance of workforce development as it relates to economic development, they are not directly tied to any economic development plans. Some of the regional efforts are part of an informal outreach to local biotech companies with regard to their workforce issues. The closest tie to the economic development side of the workforce issue has been the Chamber of Commerce's use of Austin Community College's Biotechnology Program in its presentation to companies possibly relocating to Texas.

Development of Curriculum

Because there is no distinct workforce strategy, curriculum development takes place on a case-by-case basis at each institution. Many of the programs are developed in concert with local industry and include the types of courses and skills that are applicable to companies in the biotechnology field at the technician level and above. Local biotechnology industry members sit on the boards of some of the biotechnology curriculum development committees at the institutions, and some also teach at the institutions; but, this occurs mainly on a case-by-case basis. For the most part, curriculum is geared directly toward specific company needs (e.g., ACC teaches courses in the ribonucleic acid [RNA] area because of the presence of Ambion). However, this also includes teaching the basics of lab technician work so students are prepared for work outside of Texas. Some programs (e.g., Austin Community College) actually teach in areas (e.g., bioprocessing) that are distinctly related to work in other states such as California.

Role of Experiential Learning Activities

Most of the programs geared toward biotechnology tend to offer (and some require) as part of the curriculum an internship or experiential learning activity to fully prepare students for post-graduation work—this seems to be particularly prevalent at the community college level. In the Austin region, those high schools working with ACC are beginning to make internships a requirement for the biotechnology track being offered.

Teacher Training Activities

Programs that train elementary school teachers also exist to a varied degree, with some assisting teachers in keeping up to date on the newest information in the industry. There also are programs such as those at the Alvin Community College that assist teachers in developing a biotechnology curriculum. Funding for such programs do not exist at the state level and must come from private donations (such as Monsanto, which assists the program at the Alvin Community College).

Funding of Labs and Equipment

Funding is not available at the state level, so some schools are taking a "quid pro quo" approach to funding by offering free training to some industry workers in exchange for equipment from their companies. Other institutions do offer limited funding, but it is usually combined with other sources of funding as well, including such sources as used equipment purchases from eBay that are funded by the teachers themselves. Publicly funded institutions do not allow the purchase of used equipment, a policy that needs to change according to one professor. Additionally, there are no tax deductions for companies that donate their used equipment and they incur an increased legal liability by donating. Currently, if a person gets hurt using a company's donated, used equipment, he/she has the potential for a lawsuit, which already has decreased the likelihood of company equipment donations.

Key Success Factors

- **Working with industry** to determine appropriate course material that will benefit both the employee and the employer. There is a growing demand in the industry for *adequately* trained biotechnology workers. In some cases, employers have passed up Ph.D.'s in the bioscience arena for more appropriately trained community college workers who have the specific skills that companies are seeking.

Barriers to Success

- **Lack of funding** for equipment and broad biotechnology workforce initiatives.
  - **No tax deductions** for companies that donate their used equipment.
  - **Increased legal liability by donating equipment.**
- **Lack of a cohesive strategy** has vast impacts on biotech workforce development in the state. Often one program does not know what another is doing, making it harder to combine resources that will benefit the entire regional workforce.
- **Lack of (quantitative) knowledge** of whether the supply of biotech graduates is meeting the demand by local industry. The lack of a cohesive strategy also prevents the workforce suppliers (academic institutions) from knowing whether they are teaching the right skills, unless this relationship is established by a "champion" professor.
- **Student recruitment—**Most parents greatly influence their child's choice of career. Most parents lack knowledge of the biotechnology field and the benefits a career in this field can offer.
  - **Limited salaries** in most lab-tech type of occupations are a big barrier in recruiting students who would be successful in this career.

Leading Program Activities in Texas

The Austin Community College Biotechnology Program

This is perhaps Texas's most well known and most well organized biotechnology initiative, perhaps because of its affiliation with Bio-Link. One of the main goals of the program is to work with the Texas state government to promote (1) the appropriate state funding for educational strategies that will produce the workforce and (2) the development of the industry and the movement of the bioscience industry into Texas so that there is a place for these workers to go when they graduate. This program is the newest of ACC's Math-Science programs, which enrolled its first students in the fall of 1999, to respond to the tremendous need for trained technicians in Central Texas's growing bioscience and biotechnology industries. It has become so well known that Biogen Inc. (in Research Triangle Park, NC) tried to recruit some of its graduates with salaries in the range of $40,000. ACC offers a curriculum of specialized courses taught by academics and industry professionals that gives students the basic skills and state-of-the-art techniques they'll need to fill available positions in the industry. The ACC Biotechnology Program offers not only degree and certificate programs, but also training for working professionals in the biotech industry. The program at ACC has become successful enough that it is now highlighted by the Chamber of Commerce in recruiting companies to come to the state. The program has a 100 percent placement rate to date, including many more "non-completers." The college lists the basic competencies that should be inherent in each biotechnology course at http://www2.austincc.edu/biotech/. As part of the development phase, a meeting was held with technicians from the area bioscience industry to determine the competencies that should be incorporated into the program. The first course in the Biotechnology Program sequence is offered at local area partner high schools.

ACC offers two paths:

1. **The Associate of Applied Science Degree (A.A.S.)**, which provides biotechnology experience with general education courses in the arts and sciences and is designed to prepare students for working in medical, research, and industrial laboratory areas.
2. **Certificate in biotechnology program**, which prepares students to function as entry-level biotechnicians in the laboratory or in biotechnology manufacturing. These technicians need to have the skills required for tasks such as quality control and assurance; food, water, soil, and product testing; and research and development of new products.

Both programs prepare students for transferring to four-year colleges, and the program as a whole synthesizes a broad range of disciplines—quality assurance, business, technical writing, Web management, library science, computer science, chemistry, biochemistry, biology, microbiology, and physics. Students acquire knowledge in many areas: analytical laboratory techniques; laboratory instrumentation; growth, isolation, and characterization of microorganisms; histologic techniques; and immunological techniques.

Key Contact: Linnea Fletcher, Ph.D., Office: Attaché room 219, Telephone: (512) 223-3282 *or* 223-324, E-mail: linneaf@austincc.edu. Dr. Fletcher is also the South Central Regional Director for Bio-Link.

Size of Program: In its first year, the Biotechnology Program admitted 30 students, and interest in the program continues to increase. Future plans include the hiring of another full-time faculty member with a joint appointment in Biology and Biotechnology. Two full-time faculty are needed to counsel and supervise these students, both in the classroom and as interns. Currently, the majority of students come from the existing workforce into the program; however, the Director is attempting to change this scenario through early recruitment programs beginning as early as junior high school, but focused mainly in high school. Some of the efforts to recruit these students have included starting biotechnology clubs in high school, educating parents about the benefits for their children of a biotechnology career, a bioscience video that highlights "cool, good-looking" adults in "cool" careers. A four-year biotechnology certificate also is being developed at the high school level. Many of the students are local housewives, but some students come from as far away as India and China as a result of spousal transfers and the accolades the program has received.

Faculty: Development of this program has been a collaborative effort within the college, involving both full-time and part-time ACC faculty from a variety of departments, the deans of Math and Science and Allied Health, and Learning Resource Services (LRS) staff. One full-time faculty member with a joint appointment in biology and biotechnology—Linnea Fletcher, Ph.D.—is serving as Program Coordinator. In the future, other faculty, staff, and departments—including business, philosophy, technical communications, and computer science, as well as distance learning, counseling, and advising—are expected to participate in the Biotechnology Program.

So far, faculty members have worked with industry and neighboring educational institutions (both secondary and postsecondary) to develop the biotechnology curriculum and to establish a network and community of practice in Central Texas. Participating staff from LRS have helped to identify information-literacy competencies and to develop the quality assurance curriculum. Additionally, many of the faculty at ACC have performed numerous externships, while professsionals from Central Texas's biotechnology industry (including such companies as Stratagene/Biocrest, Ambion, and ALK Abello) have lent their expertise to the ACC Biotechnology Program via on-site teaching engagements. The advisory board for the program is composed of both academic and industry leaders who oversee the current and future development of the ACC Biotechnology Program.

Curriculum: While the Director tries to cater to the local bioscience companies by developing the curriculum in concert with the skills they need, she also attempts to keep the curriculum broad enough to develop students who will fit well into any company's technician program. In the past, students have accepted positions in California, which, she recognizes, has a different bioscience economy focus than that of Texas, thus requiring a different skill set for her students. However, she does offer a "graduate guarantee" that, if students are trained in her program to do something (e.g., take apart a spectrometer) and they cannot do it, she will retrain them for free. The curriculum does, however, focus quite a bit on RNA work (mainly due to the presence of Ambion Inc.). Courses include the following:

- Introduction to Biotechnology
- Cell Culture Techniques
- Biotechnology Lab Methods/Techniques
- Molecular Biology Techniques
- Biotechnology Lab Instrumentation
- Internship Biological Technology I
- Internship Biological Technology II
- Quality Control for the Biosciences.

Special Programs: ACC also offers training and continuing education to working professionals in the biotech industry. Future content within the "On-the-Job Training" section of BIOTECH GATEWAY will include

- **Advanced competencies for biotech workers**
- **Continuing education programs**
- **Custom and contract training programs.**

Programs for K-12 students exploring their career options include opportunities to take college courses and earn credit before graduating from high school. There are two types of "Early College Start"[16] opportunities. Dual credit allows students to take ACC courses that can also count toward their high school graduation requirements. Credit-in-escrow allows students taking tech-prep courses at local high schools to receive ACC credit for those courses upon enrolling at the college.

[16] http://www3.austincc.edu/highschl/.

The ACC Biotechnology Program also has developed articulation agreements with high schools in several districts. The ACC-developed course, Introduction to Biotechnology (BITC 1311 at ACC), is offered as a year-long science elective in several Central Texas high schools. An Advanced Technological Education grant from the National Science Foundation is supporting the expansion of biotechnology education in Central Texas.

Also, in the summer of 2002 a Biotechnology Summer Institute was offered that was designed for high school teachers teaching Austin Community College's Introduction to Biotechnology course, but was open to other high school and college teachers as well. The institute lasted three weeks, and labs and activities were geared toward biotechnician workforce education with emphasis on the application of techniques and the laboratory workplace. It covered the entire content and lab procedures for the course, including DNA and protein gel electrophoresis, protein separation and analysis, polymerase chain reaction, bacterial transformations, enzyme-linked immunosorbent assay (ELISA) and immunoassay tests, plant tissue culture, bioremediation and biodegradation, bioinformatics, discussion of current biotech issues, cloning, stem cells, the Human Genome Project and genetic privacy, genetically modified foods, tours of local biotechnology labs and industry, and opportunities to learn RNA techniques.

Facilities: Presently, the Biotechnology Program is spread across several campuses—Cypress Creek, Rio Grande, and Riverside—depending upon the different courses' laboratory needs and the availability of facilities for evening courses, which the program requires to meet the needs of students and industry. To consolidate the program to one campus, and to allow other programs within the college to use the equipment acquired and required for biotechnology, the program expects to build or renovate lab spaces, prep and equipment areas, and storage space.

The new Health Sciences building, to be constructed at ACC's new Eastview Campus, is the most likely future home for the Biotechnology Program. A new home facility for biotechnology also could accommodate lab space for allied health or other lab-oriented workforce programs at ACC, such as environmental technology or chemistry technology. Presently, some of the Biotechnology Program's industry partners are working with those programs as well.

Much of the equipment at the facilities is donated by local companies (because companies recognize that they need to have workers trained properly on the appropriately equipment) as well as from "quid pro quo" investments—if the company provides the program with equipment, then the program will train some of its workers for free. However, many companies have not donated equipment because of the legal liability—if someone gets hurt on a company's used equipment, he/she may sue the company. While the school does provide some funding for equipment, it is negligible, particularly because the school/state does not allow the purchase of used equipment (again, legal liability issues), so the Director has had to go so far as to purchase some equipment herself on eBay.

Industry Partnerships: The ACC Biotechnology Program has an active internship component with industry, currently a requirement at the community college level and soon to be a requirement at the high school level as well. Some firms include Stratagene/Biocrest, Ambion, and ALK Abello.

Keys to Success:

- Modeling the program around "best practice" areas helped to make this program a success. Specifically, Linnea Fletcher did an initial "best practice" analysis of the San Diego City College biotechnology program, which employs industry technicians to develop the curriculum and teach in its program. Because they work so closely with industry, the students are trained exactly as industry needs them and most of them are hired by industry before they graduate from the program. It is from this program that the term "successful noncompleter" was developed to describe these students.

Barriers/Recommendations:

- Need to develop a booklet that is a "one-stop shop" to show companies interested in moving to the area what is available to them.
- Need to assist companies by developing friendly policies—tax credits and incentives for equipment donations, eliminating companies from legal liability for equipment donation.
- Need to better educate parents as well as students regarding the benefits of a career in biotechnology to get the best possible recruitment for these programs
- Need for more money for equipment.
- Need for industry to pay a higher salary at the technician level.

The North Harris Montgomery Community College District Biotechnology Institute

The Montgomery College Biotechnology Institute (MCBI) is an outgrowth of a successful program originally based at Montgomery College in the Woodlands outside of Houston, which was begun in 1992 and was the first biotechnology degree program in Texas. As a result, the program has been the model for the Texas Higher Education Coordinating Board and for other community colleges in Texas.

In the spring of 2001, the Montgomery College Biotechnology Institute was created to establish a centralized approach. MCBI aims to prepare students for all levels of entry into the biotechnology industry and to meet the industry's workforce and continuing education needs. The institute functions to identify and meet biotechnology industry training needs, recruit high school students, create shorter certificate programs, and partner with The University Center to articulate with four-year programs in biotechnology. The program offers an associate of applied science degree that is designed to prepare graduates for employment as biotechnicians.

Skills: Skills in cell culture, laboratory methods, molecular biology, and laboratory instrumentation are included in the courses that make up the specialized portion of this degree plan. Additionally, there is a sequence of basic sciences that is included in the plan—biology, chemistry, and microbiology.

Key Contact: Dr. Larry Loomis-Price, Director, Montgomery College Biotechnology Institute, 3200 College Park Drive, Conroe, Texas 77384, (936) 273-7060, (936) 273-7362, lloomis-price@nhmccd.edu

Curriculum: The biotechnology associate of applied science degree is awarded for successful completion of the 71 semester credit hours required in the degree plan. The biotechnology program also offers qualified students the opportunity to take individual courses within the biotechnology core courses. Students with the appropriate level of prior training may elect, for example, to take only the Molecular Biology (BIOL 2401) course to gain skills in that area.

Special Programs: The community college has an explicit articulation agreement with the campus of the University of Houston-Downtown (UHD) that entails two years of courses at Montgomery college for a total of 71 hours and a third and fourth year at the University of Houston's downtown campus for a total of 63 to 65 hours. For the resulting bachelor of science in biotechnology degree to be awarded, 129 to 131 total hours must be taken and a writing proficiency exam must be taken and passed during the third year at UHD.

Similar articulation agreements exist between the University of Texas Medical Branch (UTMB) and North Harris Montgomery Community College District (NHMCCD) for a clinical laboratory sciences program between the institutions. The idea is to provide an opportunity for qualified students who have identified clinical laboratory sciences as a career choice to receive early acceptance into the UTMB at Galveston Department of Clinical Laboratory Sciences (CLS) Program toward completion of their bachelor's of science degree. Initially, a student applies and is admitted to NHMCCD and is admitted to UTMB after passing a pre-entry interview by the faculty of the UTMB CLS Program at NHMCCD or UTMB during the first semester of the student's sophomore year.
Industry Partnerships: The internship experience occurs in the final semester of the program. Students are placed in area biotechnology companies or medical center research labs to complete their training.

The Northwest Vista College (NVC) Biotechnology Program[17]

The NVC Biotechnology Program was developed to help the local biotech community by providing industries with well-trained lab technicians. The program intends to place students in a variety of areas, including quality control/quality assurance, research and development, forensics, diagnostic laboratories, and biomanufacturing in the San Antonio area. It began in the spring semester of 2002. Since its inception, many brand new facilities for biotechnology laboratory research have been added. Due to a lack of students currently, the program has been unable to offer upper-level courses, though it intends to in the near future. It is the only biotechnology program in San Antonio and has advertised on television to recruit students, which was the most successful of the marketing efforts.
Skills: The biotechnology training program provides students with the necessary general education courses, applicable workforce skills, and biotechnology experience to successfully perform tasks required in the basic research and industrial laboratory areas. Graduates are able to follow and analyze research protocols, communicate effectively, maintain accurate records, and perform experiments using current instrumentation and procedures found in the workplace and also possess adequate computer skills. Students learn such procedures as aseptic (clean) technique, gel electrophoresis, recombinant DNA techniques, cell culture techniques, polymerase chain reaction, bacterial culturing, bacterial transformation, protein purification/separation, ELISA, and various blot techniques and restriction enzyme use. They take courses in lab methods, molecular biology, and instrumentation, and their coursework is supplemented by the mandatory internship requirement.
Key Contact: T. Neil McCrary, Biotechnology Coordinator, Northwest Vista College, 3535 N. Ellison Dr., AB 201, San Antonio, TX 78251, (210) 348-2282, (210) 348-2264 fax, tmccrary@accd.edu
Size of Program/Other: There is no focus on targeting particular ethnic groups—the first group of students happened to be mostly female (with one Hispanic male) and the second group consisted of mostly white males (with one black male). Most of the students come from the existing workforce, are in their early 20s, and have neither worked in a lab nor finished college. Roughly 24 students started in the program and half of them are still in it.
Curriculum:[18] The initial course offering included Introduction to Biotechnology (BITC 1311), followed by Laboratory Methods in Biotechnology (BITC 1402). Other courses currently or soon

[17] http://www.accd.edu/nvc/areas/biotech/default.htm
[18] http://www.accd.edu/nvc/areas/biotech/courses.htm

to be available include Cell Culture Techniques, Molecular Biology Techniques, Laboratory Instrumentation, and the Internship in Biotechnology. The program also includes courses in chemistry, microbiology, technical writing, ethics, and other courses intended to create a well-rounded lab technician. The curriculum is based on input from industry and is adjusted accordingly to fit within the Texas state guidelines for biotechnology techniques.

Special Programs: Hands-on experience in various cellular and molecular techniques includes gel electrophoresis, bacterial transformation, cell culture, protein purification and separation, polymerase chain reaction, ELISA, and various blot techniques.

High school students soon will be able to take the introduction to biotechnology course so that they can get college credits before coming into the college.

Evening courses were not well utilized by students. Also, the University of Texas at San Antonio has agreed to a joint degree program (2+2), but the details have not yet been worked out.

Facilities: At the program's inception, many new facilities were built and local companies were utilized when necessary.

Industry Partnerships: An internship opportunity in a local biotechnology laboratory is a mandatory part of the curriculum for this program. The program also coordinated with a local biotechnology company that has mammalian facilities since it does not have them on-site.

SPECIAL PROGRAMS

Texas Education Agency Biology Pilot 2002-2003

This is more or less a pilot program attempting to harness the power of Internet technology. There is no workforce development component per se, though it does assist teachers in accurately conveying to their students biology information that is in line with the requirements of the Texas Education Department. There also are pilot programs in some of the other major elementary school subjects (history, math, and social studies).

Project Summary: The biology pilot project is exploring the use of a Web interface as an access point for biology-oriented curriculum materials that are aligned with the learning standards of the Texas Essential Knowledge and Skills (TEKS) and the learning objectives of the Texas Assessment of Knowledge and Skills (TAKS) test. The curriculum materials themselves are being drawn from the Texas Library Connection (TLC). The TLC supports the K-12 learning community by providing access to over $40,000 worth of on-line resources for teachers, students, and parents. The on-line education curriculum resources are specifically associated with individual biology textbooks on the state's approved textbook list. The existing resources were leveraged and aligned as lesson plans that cover TEKS/TAKS learning objectives. A Web interface allows teachers to readily locate these materials within the Texas Library Connection Web site. It is based on content strands and the specific textbooks being used in the classroom.

Project Goals: The primary goal of the project is to extend the reach of current-generation biology textbooks by encouraging teachers to focus on TEKS/TAKS-aligned curriculum content for students by utilizing readily accessible lesson plan resources via the Web. Other goals include

- Providing teacher resources for biology TEKS aligned with TAKS objectives
- Providing resources in key areas in which students fail to meet minimum expectations on biology end-of-course exams

- Demonstrating time savings for teachers in locating and using relevant resources for targeted biology TEKS and TAKS objectives
- Demonstrating improvement in teachers' classroom use of TLC to enhance instructional strategies and improve student performance
- Developing a successful model of information dissemination and implementation training that capitalizes on existing human and technology resources.

Project Partners: The project involves a partnership between the Texas Education Agency, Region IV Education Service Center, the Gale Group, and the Publisher's Resource Group.

Teacher Summer Institute in Neurobiology at the University of Texas at San Antonio (UTSA)

The Teacher Summer Institute in Neurobiology is a two-week summer course for secondary school teachers, designed to enhance their instructional capabilities in the neurosciences. The program is sponsored by the UTSA Division of Life Science and the Howard Hughes Medical Institute. In summer 2003, 15 secondary school teachers attended the Institute.

Goals: The Teacher Summer Institute in Neurobiology has several basic goals to be accomplished during the two-week course:

- Provide a strong foundation in neuroscience concepts
- Familiarize secondary school teachers with the World Wide Web, Web page construction, and classroom application of these materials
- Introduce neurobiology lessons and activities appropriate for their students
- Provide a classroom computer to enable the teachers to utilize the Web-based activities that they have created, as well as maintain contact with the university for continued guidance throughout the school year.

Costs and Benefits: The program pays for course books and all costs involved in registering for UTSA coursework. Upon completion, the teachers receive five units of graduate credit from UTSA, a stipend ($750.00), and a personal computer to use in their classrooms.[19]

Dates: In 2003, the Teacher Summer Institute was held from June 16–June 27.

Requirements:

- Texas Teacher Certification
- Biology teacher at a secondary school in South Texas
- Must currently be employed at a school district recognized as serving students who have been historically underrepresented at the university level
- Must have an interest in neurosciences and the desire to incorporate computer technology into their classroom.

Key Contact: Dr. Gail P. Taylor, The University of Texas at San Antonio, Department of Biology, 6900 N. Loop 1604 W, San Antonio, TX 78249, office: (210) 458-5761, fax: (210) 458-5658, gptaylor@utsa.edu

[19] http://www.utsa.edu/tsi/html/*#*.

Curriculum: The Institute will consist of three components:

- Introduction to Modern Neuroscience: Lecture course. Teachers are given a thorough introduction to modern topics in neurobiology.
- The Neurolab: Experiments and demonstrations, many of which can be repeated in the classroom, complement concepts introduced during lecture.
- Using the Internet for Instructional Purposes: A computer-based course in which teachers learn to use the Internet to find pertinent neurobiology information and create on-line lessons for their students.

Keys to Success: The long-term goal of the Teacher Summer Institute is to enrich the understanding and appreciation of secondary school students for the sciences. It is hoped that the students who benefit from this program will be directed by these experiences to attend UTSA and other universities, seek a degree in the life sciences, and pursue graduate or professional training.

WASHINGTON

The bioscience industry in the state of Washington is actively engaged with state officials and educational leaders to cultivate a statewide system that prepares individuals for positions in the biosciences. The nature of interaction between state, industry, and educational institutions is quite unique. Industry works with educators and state leaders to assess skill needs, design curriculum, and place students into jobs.

The primary explanation for the heightened level of collaboration is the result of a large bioscience industry base within the state of Washington. According to the 2002 Washington Biotechnology and Medical Devices Association's annual report[20], the industry employed just under 19,000 in 2001. The industry projects that by 2005 employment will total more than 23,000. In addition to industry activity, several leading-edge research institutions across the state also have contributed significantly to the biosciences.

The size of the state's existing industry, combined with a profound level of interaction between industry and educational leaders, has enabled the state of Washington to create a comprehensive strategy for workforce development. The programs that stem from these partnerships are broad in both scale and scope. The relationships have significance not only for the future workforce, promising that they possess necessary skills, but also for ensuring a system that is capable of adapting with the ever-changing environment of the highly innovative bioscience industry.

OVERVIEW OF WASHINGTON ACTIVITIES

Focus of Bioscience Workforce Development Programs

The state of Washington has not instituted any one particular program, but has cultivated a framework that engages each of the players in bioscience workforce development. Each party with an interest in creating highly skilled and knowledgeable workers is drawn on to ensure that programs are cohesive at every level of worker development. This requires a very high level of coordination, which the state of Washington has successfully implemented.

The workforce programs and initiatives in Washington are all primarily geared toward bioscience research, reflecting the emphasis of the state's industry and research institutions. Although each level of Washington's educational infrastructure is actively involved developing programs to train and educate workers, the state's community colleges have been at the center of workforce development.

The state's community colleges have taken the lead on several initiatives. The structure of the two-year colleges allows the institutions to bridge between high schools and universities, while simultaneously addressing the needs of incumbent workers. The community colleges also have been extremely instrumental in organizing and managing the state's initiative to identify industry skill standards for bioscience research.

Even though the community colleges have taken a major leadership role, the emphasis across all educational and training initiatives is on providing individuals with knowledge and skills applicable to the bioscience industry. Whether programs take place at the high school,

[20] *2002 Washington Biotechnology and Medical Technology Annual Report,* published by Info.Resource Inc. in cooperation with the Washington Biotechnology and Biomedical Association.

community college, or university level, the state of Washington has created a highly collaborative system focused on coordinating industry needs with biotechnology workforce programs. Merely identifying bioscience workforce development is a unique endeavor. Indicating bioscience workforce development as a priority brings together the players necessary to determine how best to address the issue. Essentially, the state has realized that coordination is key for successful programs.

Range of Program Development and Linkages

The workforce programs in Washington are highly integrated across the academic spectrum. The community colleges play a critical role in developing the linkages between the various educational institutions. Some of these linkages can be quite formal. Formal linkages require educational institutions to work together to design courses and curricula in such a way that a student is able to transfer from one level to the next. Other linkages are informal, taking form as outreach programs. However, even outreach programs require a certain level of coordination among academic institutions and service providers to ensure that the particular program is in line with identified bioscience skill standards and industry needs.

- K-12 institutions have worked closely with higher education to ensure that students and teachers are prepared to pursue education in the field of bioscience research. The partnerships the K-12 institutions develop with higher education have formal and informal aspects.
  - K-12 schools work with community colleges to develop biotechnology-specific curricula and courses. Two schools have even created biotechnology programs that teach advanced techniques such as polymerase chain reaction (PCR) and gene sequencing. These types of programs are directly linked to programs offered at community colleges. One school has created a biotechnology academy, offering several integrated courses geared toward preparing students for a future in the biosciences.
  - K-12 schools work with universities to educate students and teachers about cutting-edge scientific techniques in the bioscience field. These programs provide teachers with professional development opportunities in the specific field of deoxyribonucleic acid (DNA) sequencing, genomics, and bioethics. The programs also help K-12 teachers identify best practices in curriculum development and integration.
- Community colleges work extensively with K-12 schools and universities to articulate and implement courses and programs that are easily transferable and that adhere to statewide identified skill standard guidelines. This coordination requires that the community colleges collaborate with nonacademic institution workforce training providers.
- The level of involvement universities have in designing programs that link to other levels of education is limited. Beyond outreach programs, relationships tend to be informal. Universities tend to be engaged more with sophisticated bioscience research companies that require a high level of science comprehension. However, the fact that universities have developed programs that meet the requirements of industry allows them to inform lower grades about the basic skills necessary to pursue research-intensive tracks.

Student Recruitment

The horizontal and vertical relationships that exist between industry and education are critical for recruiting students. Working with companies, schools are able to clearly identify positions and the necessary skills that will be required of future workers. The vertical relationships that have developed across the educational systems allow institutions to inform students of the opportunities in the field of bioscience research and clearly identify career paths for students. This and the economic health of the state's bioscience industry have been the most successful recruiting tools.

Strategic State Assessment

Washington has recently undergone an extensive needs assessment of the bioscience industry. A task force of community colleges, labor, businesses, universities, and K-12 schools, through funding from the state of Washington's Workforce Development Fund, created the skill standards guideline[21] for the state. The Biotechnology/Biomedical Skill Standards Project had two phases. The first phase developed and validated crucial industry skill sets within two target areas: (1) research, development, and manufacturing and (2) regulatory affairs and clinical trials. The second phase of the project focused on articulation and gap analysis of existing and future biotechnology educational programs at K-12 schools, community colleges, and universities as they related to the skills identified in Phase I.

This initiative has been a driving force in the state of Washington. The project helped to validate existing programs and encourage new ones to begin. The study also helped to solidify working relationships between and across educational institutions and industry. Though programs are developed by each institution on its own, the project has helped to ensure that programs are cohesive and relate to one another.

Leading Washington Program Activities

Northwest Biotechnology/Biomedical Education and Careers Consortium[22]

The Northwest Biotechnology/Biomedical Education and Careers Consortium is a collaboration of local-area schools and colleges offering biotechnology/biomedical educational programs, as well as companies and organized labor in the biotechnology/biomedical industry. The purpose of the consortium is to prepare people for employment in the biotechnology/biomedical field. Essentially, the consortium acts as a clearinghouse of biotechnology career and educational programming throughout the state. The goals of the consortium are to

- Provide information on biotechnology/biomedical careers
- Provide information on biotechnology/biomedical education and training
- Align educational program learning outcomes with industry skill standards
- Articulate educational skill standards between educational programs in the Puget Sound region
- Provide resources for faculty to start new or supplement existing biotechnology/biomedical programs.
- The consortium accomplished these goals in three phases[23]:
- Phase I: Developed and published Biotechnology/Biomedical Skill Standards.

[21] http://www.wa-skills.com/
[22] http://elmo.shore.ctc.edu/NWBBECC/default.htm.
[23] Full reports relating to both Phase I and Phase II of the Biotechnology/Biomedical Skill Standards Project are attainable from the following Web site: http://www.wa-skills.com/html/biotech&biomed.html.

- Phase II: Aligned two-year and four-year college curricula with Biotechnology/Biomedical Skill Standards and developed tools and models to support articulation between high schools and two-year and four-year colleges.
- Phase III:
  - High School: Developed a high school student career information brochure. Developed tools and best practices to start a high school biotechnology program.
  - Colleges: Developed model college capstone projects and portfolios. Developed short courses for advanced training of professionals in the biotechnology/biomedical industry. Developed a tech prep course. Identified internship best practices. Disseminated information relating to biotechnology/biomedical fields. Designed a Web site to provide access to Phases I, II, and III outcomes and other biotechnology/biomedical information.

The consortium was formed from the Biotechnology/Biomedical Skill Standards Project.

Shoreline Community College

Biotechnology Laboratory Specialist Program[24]

The Biotechnology Laboratory Specialist Program at Shoreline Community College prepares students for careers in biotechnology research and development. The program goal is to provide practical knowledge, hands-on learning, and familiarity with cutting-edge techniques, technologies, and equipment. Degree and certificate candidates intern in local biotechnology labs as part of their programs of study.

The program is specifically designed to articulate to four-year curricula should a student decide to pursue an advanced degree. Not only are students able to apply their education to four-year institutions, but close relationships with companies assure students are receiving the required industry skill sets to obtain employment.

Key Contact: Berta Lloyd, Assistant Vice President of Workforce and Economic Development, Director of Professional/Technical Development, Shoreline Community College, 16101 Greenwood Avenue, North, Seattle, Washington 98133, (206) 546-4595, blloyd@shore.ctc.edu

Size of Program: Currently, 40 students are enrolled in the program. Approximately 60 percent of the students already possess a bachelor's degree in the sciences. The program has two full-time faculty members and six part-time.

Program Specifics/Curriculum: The Biotechnology Program offers students great flexibility. The A.A.A.S. degree is a two-year program for those without a science background. The first year curriculum provides a foundation in math and basic sciences. The second year focuses on applied biotechnology and includes courses in molecular biology, chemistry technology, recombinant DNA, immunology, and tissue culture.

The Certificate of Proficiency is a one-year program for students with prior scientific training and/or experience.

Individual and upgrade courses are available for those currently working in the field to update or expand their skills. Courses include all those offered in degree and certificate programs, plus specialty classes in areas such as regulatory, high-performance liquid chromatography (HPLC),

[24] http://elmo.shore.ctc.edu/biotech/applicants.html.

good manufacturing practices, expression technologies, and quality assurance. Key courses include

- Introduction to molecular biology, examining the molecular structures and processes that underlie cellular function
- Theory and concepts of recombinant DNA techniques
- Immunology concepts and laboratory procedures, including antigen and antibody structure and function, the genetic basis of antibody production, humoral and cellular based immunity, role of the major histocompatibility complex, control mechanisms, autoimmunity, innate and acquired immunity
- Biotechnology techniques currently prevalent in the manufacturing and production aspect of the biotechnology industry with a main focus on the isolation and purification of proteins.
- Tissue culture, addressing the theory and concepts of animal cell and tissue culturing including fundamentals in tissue culture techniques, subculturing, and maintenance of cell lines
- Media and solution preparation as a laboratory course in the preparation of solutions and media commonly used in the biotechnology industry.

Shoreline also offers a range of short training courses on specific techniques to help technicians and research assistants expand and update their skill base and enhance their employability. The courses were developed by a consortium of biotech and biomedical industry representatives and are taught by industry experts in the evenings or on weekends. The courses include flow cytometry, HPLC, applied math for biotechnology, cloning and expression, plant and animal tissue culture, and introduction to bioinformatics.

Keys to Success: Currently, the school enjoys a 100 percent placement rate. This has been aided by the fact that 95 percent of the bioscience industry is within the Puget Sound region. The school's ability to maintain close relationships with K-12 institutions, four-year colleges and universities, as well as industry has been the primary reason for the program's success. The collaboration of these organizations ensures that Shoreline's program addresses each and every entry point in the industry. This includes ensuring that K-12 students remain interested and pursue bioscience degrees.

Ballard High School (BHS)

Biotechnology Career Academy[25]

A specialized learning program that brings together science, mathematics, and language arts to prepare students for advanced study and a career in science.

Students may enter the program during their freshman or sophomore years. Students entering the program must qualify for integrated math 2 (have completed math 1 or algebra). There is an application process for all students, which includes assignment to BHS for ninth graders.

The staff in the Biotechnology Career Academy is committed to the academic success of every student in the program. Academic support will be provided for students either directly with the staff and/or in conjunction with other BHS services, including tutoring, extra study sessions, advising, and providing extra support materials. These services are available for every student in the program as well as students who would like to enter the program the following year. As part

[25] http://ballard.seattleschools.org/academics/academies/biotech.html#Anchor-11481.

of its efforts to include all students, the program is committed to helping bring any interested student up to the necessary academic entrance requirements.

- **Key Contact:** Penny Pagels, 1418 NW 65th Street, Seattle, Washington 98117, (206) 252-1000
- **Size of Program:** Sixty students are selected to enter the program each year. Of those 60 students, 30 begin the program their freshman year and 30 begin their sophomore year.

Curriculum: In the Biotechnology Career Academy, students are encouraged to learn how science, math, and language arts work together. They study advanced mathematics and use it in the context of biology, chemistry, genetics, and physics. This program offers a rigorous study of reading and writing that will promote connections between science and literature with an emphasis on scientific discovery. There also is extra help for those who struggle with math or just want to get ahead. Students enjoy exciting hands-on labs, working with the same high-tech equipment used by scientists. Students get the opportunity to do extended labs, using two class periods when necessary.
Industry Partnerships: In addition to taking integrated academic courses, students qualify to apply for a mentorship and an internship with participating scientific partners. The mentorship experience takes place during the third year of the program. The internship experience takes place after the mentorship. At the culmination of the internship experience, students will have the basis for their senior project. The senior project is completed before graduation from BHS and under the supervision of an academy staff person.

Juanita High School

Vocational Biotechnology Program

Students of the Juanita High School Vocational Biotechnology Program learn the basis of scientific developments, as well as many of the laboratory skills associated with them. This program is designed to introduce students to a variety of techniques used in biotechnology and molecular biology through the use of hands-on laboratory training. Students develop extensive skills in preparing the materials and using the equipment necessary in a research or industrial laboratory setting. Ethical considerations regarding the use of genetic material and career options in the field are explored. Students who have an interest in sciences and the biotechnology field, in particular, are encouraged to enroll. The program is available to students from surrounding school districts through the Northeast Vocational Area Cooperative (NEVAC), a consortium of eight cooperating high schools in the Seattle area.
Key Contact: Mary Glodowski, 10601 NE 132nd Street, Kirkland, Washington 98034, (425) 823-7600, mglodowski@lkwash.wednet.edu
Curriculum: Students are involved in projects that include DNA sequencing, PCR analysis, protein isolation and purification, bioinformatics, and techniques used in immunology studies. Students also work with researchers from industry and academic outreach programs. Students learn to perform laboratory techniques with precision and work independently to solve problems. Written and oral communication is emphasized in the classroom in the same way that they are used in a laboratory setting. Prerequisites: Completion of biology with a grade of B or better, previous or concurrent enrollment in chemistry.

Shorewood High School

Biotechnology Program

In response to the rapidly growing biotechnology industry in the Pacific Northwest, Shorewood High School has developed a program to involve students in cutting-edge scientific research. This biotechnology year-long course is designed for students with an interest in these sciences:

- Genetics
- Microbiology
- Immunology
- Molecular biology.

In addition, students enrolled in the biotechnology course at Shorewood High School can earn occupational credit either through Shorewood or through the NEVAC program.

Skills required for the course include a strong science background in biology and chemistry, good analytical skills, and the ability to be detail oriented. Organizational and communication skills are emphasized throughout this course. Prerequisites: B average or better in biology and chemistry or B average or better in biology and concurrent chemistry with permission of the teacher.

Key Contact: Connie Kelly, 17300 Fremont Avenue North, Shoreline, Washington 98133, (206) 361-4372, connie.kelly@shorelineschools.org

Curriculum: This course allows students to explore exciting topics such as PCR, gene sequencing, genetic engineering, transformation, and various other techniques currently used by scientists in the workplace. It is specifically designed for those interested in pursuing a career in this field. The class is constantly changing as new information is gathered from industry and each student is tied into the occupational world. Classroom experiences include participation in the Human Genome Project, independent research, visits to laboratories, guest speakers, career readiness activities, student leadership involvement, and ethical discussions.